King County

# Geotechnical Investigation

## SE Reinig Road Embankment Failures
## Slope Stability Analyses
## Project NO. 1132628

April 2019

Prepared By:


King County

Department of Local Services
Road Services Division
Materials Laboratory
155 Monroe Avenue NE, Bldg. D
Renton, WA 98056-4199

King County
**Road Services Division**
Materials Laboratory
Department of Local Services
RSD-TR-0100
155 Monroe Avenue Northeast, Building D
Renton, WA 98056-4199
www.metrokc.gov/roads

April 29, 2019

TO: Mark Beggs, P.E., Engineer II, River and Floodplain Management Section, Water and Land Resources Division, KCDNRP

VIA: Alan Corwin, P.E., Materials Engineer, Materials Laboratory, Traffic and Engineering Services Section, KCDOT

FM: Doug Walters, P.E., Engineer III, Materials Laboratory, Traffic and Engineering Services Section, KCDOT

RE: **SE Reinig Road Embankment Failures**
**Slope Stability Analyses**

As requested, we have completed a geotechnical investigation along sections of SE Reinig Road experiencing active erosion and slope instability. The purpose of our investigation is to evaluate the current site soil and groundwater conditions and to perform stability analyses to determine the probable cause and nature of the slope instability. We also developed and performed stability analyses on proposed alternative repairs provided by the DNRP.

We trust this information is of assistance to you. If you have any questions or require additional clarification, please contact Alan Corwin at 206-477-1853 or Doug Walters at 206-477-2112.

# TABLE OF CONTENTS



## FIGURES (Following Text)



## APPENDICES

# SE REINIG ROAD EMBANKMENT FAILURES
# SLOPE STABILITY ANALYSES

## 1.0 INTRODUCTION

### 1.1 Background

As requested, we have completed a geotechnical investigation along sections of SE Reinig Road experiencing active erosion and slope instability. Loss of riprap armoring has led to substantial erosion of the riverbank at four locations. The damage is developing within the SE Reinig Road Revetment near the confluence of the three forks of the Snoqualmie River, at approximately river mile (RM) 41.8. All four sections of riverbank will require slope repair. Proposed mitigation measures provided by the King County Department of Natural Resources and Parks (DNRP) includes the use of rock slopes, reinforced slopes, and soft bank stabilization measures. In addition, engineered log jam structures are proposed to be placed at strategic locations along the toe of the riverbank.

The slope failures were originally identified during annual low flow inspection conducted by boat on September 15$^{th}$, 2016 (Garric, DNRP). We understand the revetment, consisting of riprap, was originally constructed in the 1960's to protect SE Reinig Road from lateral migration of the river. The site is located in the Three Forks Natural Area on two parcels (332408-9005, 3324089059) owned by King County Parks. The general project location is provided in Figure 1, following the conclusion of the text.

SE Reinig Road is a two lane paved rural arterial that parallels the revetment and is generally aligned west to east. The outer road shoulder is approximately 25 feet in width between the pavement and top of the river embankment. The embankment ranges from about 20 to 25 feet in height. The existing revetment, near the vicinity of the damaged sections, consists of riprap armoring along the lower 6 to 8 feet of the embankment. Rock armoring on the revetment is not uniform. Some areas are composed of larger 3 to 4 man rock while other sections consist of light loose riprap size or smaller material. Based on observation, the riprap was placed on the surface of the bank and does not appear to have been keyed into the toe of the slope at the time of construction.

### 1.2 Purpose

The purpose of our investigation is to evaluate the current site soil and groundwater conditions and to perform stability analyses to determine the probable cause and nature of the slope instability. We also developed and performed stability analyses on proposed alternative repairs provided by the DNRP.

## 2.0 SUBSURFACE CONDITIONS

### 2.1 Geologic Mapping

We reviewed the 2009 Geologic Map of the Snoqualmie 7.5-minute quadrangle, compiled by Dragovich, J.D et al. This map was provided online by the United States Geological Survey in a scale of 1:24,000. Based on our investigation and mapping, the following surficial geologic units may be present in the general area of the site.

**Artificial fill (Af):** Though not shown on mapping, significant depths of fill underlies the roadway and outer road embankment within the project limits.

**Landslide Deposits ($Q_{ls}$):** Diamicton of silty sandy gravel with boulders and cobbles, contains minor sand or gravel beds where modified by stream processes.

**Alluvium Deposits (Qa):** Moderately sorted deposits of sandy silt, pebbly sand, cobble gravel, and boulders deposited along major river and stream channels; less coarse deposits of fine sand, silt, clay, and peat are accumulated in the low energy parts of river valleys subject to seasonal flooding. Alluvium is the predominant geologic unit underlying the subject site.

### 2.2 Geotechnical Drilling

To investigate subsurface conditions, we drilled four hollow stem auger borings within the project limits. All borings were drilled using a track-mounted Diedrich D-50 drill rig equipped with 3-¼ inch inside diameter hollow stem augers. Standard Penetration Tests (SPT) were taken at 2.5 foot intervals for boring depths up to 20 feet. Below 20 feet, the testing intervals were increased to 5 feet. The SPT provides a measure of compaction or relative density of granular soils, and consistency or stiffness of cohesive fine-grained soils. Representative soil samples were collected and returned to our laboratory for identification and testing. Approximate boring locations are shown in Figure 2. Detailed copies of the boring logs (Figures A-1 through A-4) are provided in Appendix A.

#### Shoulder Borings: B-1 and B-2

Boring B-1 was drilled in the outer road shoulder of SE Reinig Road near the top of the riverbank. In B-1, up to 10 feet of loose to medium dense sandy silt to silty sand fill overlies dense silty gravel (fill?) to a depth of 17.5 feet below the ground surface (bgs). Underlying the silty gravel, dense to very dense poorly graded sand, gravel, and numerous cobbles were observed to a depth of 25 feet bgs. Below 25 feet, medium dense to very dense interbedded sand and sandy silt deposits were encountered to the termination depth of the boring at 71.5 feet. B-1 was completed as a monitoring well.

Boring B-2 was also drilled in the outer road shoulder of SE Reinig Road near the top of the riverbank. In B-2, up to 10 feet of loose sandy silt fill overlies dense silty gravel (fill?) to a depth of 19 feet below the ground surface (bgs). Underlying the silty gravel, dense to very dense poorly graded gravel with silt and numerous cobbles was observed to a depth of 27 feet bgs. From 27 to 35 feet bgs, medium dense poorly graded sand and sandy silt deposits were encountered. Below 35 feet, the soils changed to very dense gravel and cobble to the termination of the boring at 37 feet bgs. B-2 was completed as a monitoring well.

**Roadway Borings: B-3 and B-4**

Boring B-3 was drilled in the center of the westbound travel lane of SE Reinig Road across from B-1. In B-3, 6 inches of ACP overlies medium dense silty sand with gravel fill to 3 feet bgs. From 3 to 8 feet bgs, the soils change to very loose to loose sandy silt fill. Below 8 feet bgs, the soils generally consisted of medium dense to dense sands and dense to very dense silty sands to the termination of the boring at 51.5 feet. Groundwater in B-3 was estimated at a depth of 15.5 feet bgs at the time of drilling.

Boring B-4 was drilled in the center of the westbound travel lane of SE Reinig Road across from B-2. In B-4, 5.5 inches of ACP overlies medium dense silty sand with gravel fill to 3.5 feet bgs. From 3.5 to 9 feet bgs, the soils changed to very loose sandy silt fill followed by very dense poorly graded gravel fill. Below 9 feet bgs, the soils generally consisted of medium dense to dense sands and silty sands to the termination of the boring at 51.5 feet. Groundwater in B-4 was estimated at a depth of 15.0 feet bgs at the time of drilling.

## 2.3 Groundwater

Groundwater was observed in all boreholes during drilling. We expect groundwater elevations to fluctuate in response to changes in river elevation and seasonal precipitation. Estimated groundwater levels observed during drilling are presented below in Table 1.

**Table 1: Estimated Groundwater Levels During Drilling**

| Boring | Date Drilled | Feet Below Surface | Estimated Groundwater Elevation |
|---|---|---|---|
| B-1 | 5/30/2018 | 17 feet | 405.8 feet |
| B-2 | 5/30/2018 | 15 feet | 407.9 feet |
| B-3 | 5/29/2018 | 15.5 feet | 410 feet |
| B-4 | 5/29/2018 | 15 feet | 411 feet |

## 2.4 Monitoring Well Construction

Monitoring Well B-1 consists of a two-inch inside diameter blank PVC pipe with 20-slot well screen. The screen was prepacked and installed from about 30.0 feet to 20.0 feet below the ground surface (bgs). The annular space around the screen was filled with a clean 10-20 uniform sand filter to a depth of about 18 feet. Blank PVC casing was installed above the screened well section to about the original ground surface. The remaining depth to the near surface elevation was backfilled with bentonite chips and capped with redi-mix concrete. B-1 is protected with a flush mount protective steel cover. The monitoring well was constructed in general accordance with the Washington State Department of Ecology (DOE) WAC 173-160 “Minimum Standards for Construction and Maintenance of Water Wells” and is identified by the DOE discrete well tag number BKZ 554.

Monitoring Well B-2 consists of a two-inch inside diameter blank PVC pipe with 20-slot well screen. The screen was prepacked and installed from about 35.5 feet to 25.5 feet bgs. The annular space around the screen was filled with a clean 10-20 uniform sand filter to a depth of about 23 feet. Blank PVC casing was installed above the screened well section to about the original ground surface. The remaining depth to the near surface elevation was backfilled with bentonite chips and capped with redi-mix concrete. B-2 is protected with a flush mount protective steel cover. The monitoring well was constructed in general accordance with the DOE WAC 173-160 “Minimum Standards for Construction and Maintenance of Water Wells” and is identified by the WSDOE discrete well tag number BKZ 553.

# 3.0 SLOPE STABILITY ANALYSES

## 3.1 Existing Slope Condition

DNRP provided several cross sections at strategic locations within the subject site. Based on the slope height, inclination, and soil conditions, we determined the Typical Section C-C, STA. 04+71 as the critical cross section to model. Soil and groundwater conditions identified in soil borings B-1 and B-3 were transposed onto the STA. 04+71 cross section to develop a simplified model for subsequent slope stability analyses.

Preliminary slope stability analyses of the critical embankment section were performed utilizing the software program, Galena, developed by Clover Associates Pty, Limited. For our stability computations, the Simplified Bishop Slip Circle analysis option was utilized. This program employs limit equilibrium force resolutions to arrive at a factor of safety (FS) for the critical slope section. A factor of safety of 1.0 represents a condition of imminent failure.

For this slope stability analyses, we followed the general guidelines as set forth in the US Army Corp of Engineers (COE) Engineering Manual EM 1110-2-1902 (Slope Stability). The required slope factors of safety provided in EM 1110-2-1902 Table 3-1 are for new earth and rock-fill dams and are not required values for a riverbank. Even so, as recommended by the COE, we are utilizing the target factors of safety for general guidance of the riverbank slope stability. Riverbanks are subject to fluctuations in water level. Therefore, low water and drawdown events are conditions that were considered in the stability analyses. For low water, a target FS of 1.3 is considered an acceptable factor of safety. For drawdown, the target FS is 1.1 to 1.3.

## Model Soil Parameter Development

Based on observation, the slope failures at this site have been shallow. In addition, the subject slopes appear to be marginally stable indicating a factor of safety slightly greater than 1.0. In order to develop a conservative slope model for subsequent analyses, we incorporated a shallow slip failure that generally matched the observed site conditions. We then utilized the back-calculation feature in Galena to establish the soil parameters required to achieve a factor of safety near 1.0. In addition, standard penetration blow counts obtained in the field were corrected for hammer efficiency and overburden ($N1_{60}$). These corrected $N1_{60}$ values were used to further refine the soil parameter values used in design. Simplified slope model parameters developed from the existing conditions were utilized for all subsequent slope analyses. The soil values developed for this scenario are shown below in Table 2.

**Table 2: Stability Analysis Soil Parameters**

| Profile | Soil Type | Unit Weight (pcf) | Friction Angle (degrees) | Cohesion (psf) |
|---|---|---|---|---|
| 1 | Loose Silty Sand/Sandy Silt | 115 | 32 | 50 |
| 2 | Loose Silty Sand/Sandy Silt (bwt) | 120 | 32 | 50 |
| 3 | Dense Silty Gravel | 130 | 36 | 70 |
| 4 | Dense Silty Gravel (bwt) | 135 | 36 | 70 |
| 5 | Dense Poorly Graded Gravel | 135 | 38 | 0 |
| 6 | Dense Silty Sand/Sandy Silt | 120 | 35 | 0 |
| 7 | Dense Silty Sand/Sandy Silt (bwt) | 125 | 35 | 0 |
| 8 | Dense Sandy Silt/Silty Sand | 130 | 36 | 0 |

## Low Flow and Drawdown Conditions

Water ponding against an embankment provides a stabilizing load on a slope. When the water recedes to the low flow condition, the stabilizing load is no longer in place creating the potential for slope instability. For the low flow condition, we evaluated the embankment when the river water elevation is set at 402.9 feet (NAVD 88). Multiple analyses with range constraints were selected. Based on our analyses, the low flow condition FS for the existing critical cross section is 1.06.

Based on our experience, riverbank instability is generally associated with winter drawdown conditions. Drawdown instability occurs when the river elevation drops at a rate exceeding the drainage capacity of the soil in contact with the river. The differential head between the free water and trapped soil water develops an unbalanced destabilizing pressure in the soil, causing movement to occur. In an effort to model drawdown conditions, we assumed the winter water level within the embankment matches the stream elevation ordinary high water (OHW) steady state condition. During prolonged storm activity, the water level rises within both the river and adjacent embankment. After the storm event, the water level in the river lowers back down to the OHW steady state condition. However, the water level in the embankment drops at a slower rate, dependent on the permeability of the soil.

For this site, the embankment soils consist of silty sand/sandy silt and silty gravel. For instantaneous drawdown condition modeling, we assumed that for every foot of river drawdown, the water level in the soil would drop at a rate of about 0.75 feet. For modeling, we chose a high water condition of Elevation 428.4 feet (NAVD88) and a post storm river elevation of 407 feet (NAVD 88). This creates a conservative head differential of 5.5 feet between the contact soil and the river. Based on our analyses, the instantaneous drawdown condition FS for the existing critical cross section under these assumed conditions is 0.62.

The results of our existing conditions stability analyses, and the associated target FS, are summarized below in Table 3. Diagrams showing the critical failure surfaces and associated safety factors are provided in Appendix B.

**Table 3: Existing Slope Modeled Factors of Safety**

| Modeled Condition | FS | Target FS | Figure |
|---|---|---|---|
| Low Flow | 1.06 | 1.3 | B-1 |
| Drawdown | 0.62 | 1.1 to 1.3 | B-2 |

### 3.2 Alternative Repair

Proposed mitigation measures from DNRP to stabilize the damaged embankment areas include the use of rock slopes, reinforced geogrid slopes, and soft bank stabilization measures. In addition, engineered log jam structures are proposed to be placed at strategic locations along the toe of the riverbank.

We modeled two typical mitigation sections provided by DNRP to determine the FS during low flow and drawdown conditions. The first section is an engineered log jam structure with a 1.5H:1V slope. The log jam structure sits atop scour and toe rock and is held in place with steel piles. The slope above the log jam is inclined at 1.5H:1V and consists of a combination of riprap, Class B rock, and a reinforced geogrid slope. A 2H:1V slope, several feet in height, will be placed above the reinforced geogrid slope in order to install native plantings.

The second typical mitigation section consists of a 1.5H:1V rock slope with a 2H:1V upper soil slope. A foundation keyway approximately 10 feet in width will be excavated at the toe of the slope and backfilled with 3 to 4 man rock. The rock slope above the keyway will consist of a combination of riprap and Class B rock. As in the log jam section, a 2H:1V soil slope will overlie the 1.5H:1V rock slope in order to install native plantings.

Material properties used in the stability analyses of the two typical mitigation sections are provided below in Table 4. As seen in Table 4, a cohesion value of 1000 psf is added to the reinforced slope in order to keep the critical circle away from the geogrid section. In reality, the reinforced slope does not have a cohesion value.

| Table 4: Stability Analysis Soil Parameters | | | | |
|---|---|---|---|---|
| Profile | Soil Type | Unit Weight (pcf) | Friction Angle (degrees) | Cohesion (psf) |
| 1 | Loose Silty Sand/Sandy Silt | 115 | 32 | 50 |
| 2 | Loose Silty Sand/Sandy Silt (bwt) | 120 | 32 | 50 |
| 3 | Dense Silty Gravel | 130 | 36 | 70 |
| 4 | Dense Silty Gravel (bwt) | 135 | 36 | 70 |
| 5 | Dense Poorly Graded Gravel | 135 | 38 | 0 |
| 6 | Dense Silty Sand/Sandy Silt | 120 | 35 | 0 |
| 7 | Dense Silty Sand/Sandy Silt (bwt) | 125 | 35 | 0 |
| 8 | Dense Sandy Silt/Silty Sand | 125 | 36 | 0 |
| 9 | Geogrid Wrap w/ Gravel Borrow | 125 | 34 | 1000 |
| 10 | Riprap | 120 | 40 | 0 |
| 11 | Medium Well Graded Gravel | 130 | 36 | 0 |
| 12 | Class B Rock | 130 | 38 | 0 |

## Static Stability Analyses

We analyzed the two typical mitigation sections based on the low flow and drawdown conditions describe in our earlier analyses. Multiple analyses with range constraints were selected. The results of our reinforced slope stability analyses, and the associated target FS, are summarized below in Table 5. Diagrams showing the critical failure surfaces and associated safety factors are provided in Appendix B.

| Table 5: Typical Mitigation Sections Modeled Factors of Safety (Static) | | | | |
|---|---|---|---|---|
| **Section** | **Modeled Condition** | **FS** | **Target FS** | **Figure** |
| ELJ/1.5H:1V Slope | Low Flow | 1.57 | 1.3 | B-3 |
| ELJ/1.5H:1V Slope | Drawdown | 1.42 | 1.1 to 1.3 | B-4 |
| 1.5H:1V Rock Slope | Low Flow | 1.54 | 1.3 | B-5 |
| 1.5H:1V Rock Slope | Drawdown | 1.37 | 1.1 to 1.3 | B-6 |

Our analyses indicates the two typical mitigation sections would bring embankment stability to acceptable levels for the analyzed static conditions.

## Seismic Stability Analyses

Required seismic loading conditions for non-critical structures is not provided in the referenced COE manual. The WSDOT Geotechnical Design Manual M 46-03 (Section 9.2.3.1) requires seismic analyses for only portions of the new embankment that could impact critical adjacent structures such as bridge abutments and foundations or nearby buildings. Therefore, though not required, seismic analyses were performed to verify the embankment would meet a FS of 1.1 or greater under seismic loading conditions.

The site and soil criteria used for foundation design recommendations provided in this report are in general conformance with the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications, 8th Edition, November 2017, and the current Washington State Department of Transportation (WSDOT) Bridge Design Manual (BDM), M23-50. The seismic provisions of the AASHTO Manual are based on a design earthquake having a seven percent probability of exceedance within a 75-year period. An earthquake event with this probability of exceedance has a return period of about 975 years.

Spectra, software developed by the WSDOT Bridge and Structures office, was used to generate the site specific design response spectrum, based on USGS regional probabilistic ground motion seismic hazard maps, with updated site coefficients for PGA and $F_a$ provided in the BDM. The seismic hazard maps were developed for AASHTO Site Class B. Based on the underlying soil profile, we determined the site is characterized most closely with AASHTO Site Class D. Spectra computes a design response spectrum using the Three-Point method defined in the AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition, 2011.

From Spectra, we utilized a peak ground acceleration (PGA) of 0.338 g with a site specific $A_s$ of 0.426 g. Assuming the slope can accomadate one to two inches of permanent displacement, seismic displacement analyses (Section 6.2.2 of FHWA-NHI-032) were utilized to obtain a horizontal acceleration coefficient of 0.170 g at the site for the design seismic event. Seismic modeling was completed for the low flow rock and reinforced rock sections. The results of our seismic analyses, and the associated target FS, are summarized below in Table 6. Diagrams showing the critical failure surfaces and associated safety factors are provided in Appendix B.

**Table 6: Typical Mitigation Sections Modeled Factors of Safety (Seismic)**

| Section | Modeled Condition | FS | Target FS | Figure |
|---|---|---|---|---|
| ELJ/1.5H:1V Slope | Low Flow | 1.11 | 1.1 | B-7 |
| 1.5H:1V Rock Slope | Low Flow | 1.10 | 1.1 | B-8 |

# 4.0 CONCLUSIONS AND RECOMMENDATIONS

## 4.1 Probable Cause of Failure

Based on our subsurface investigation, modeling, and observations, the current bank failures are shallow in nature with no indication of deeper-seated bank instability. The embankment generally consists of low plasticity gravels, sands, and silty sands that are prone to particle erosion from river forces. Overtime, the existing riprap that protected the embankment has been displaced. It appears the riprap was not keyed in and was likely dislodged by river scour. Without the riprap, the erosive hydraulic forces of the river are able to scour and attack the toe area of the slope, creating zones of oversteepened and cantilevered slopes that slump over time. In addition to the loss of bank from particle erosion, the current slope is also prone to shallow seated drawdown failures, especially once the slope has been oversteepened from the erosive action of the river.

### 4.2 Permanent Repair

Based on modeling, the typical ELJ/1.5H:1V slope and 1.5H:1V rock slope embankment sections shown on the plans will meet the target FS during low flow and drawdown conditions. In our opinion, as is typically the case with rivers, the key to long term stability of the reconstructed slope will be to protect the toe zone of the embankment from erosion and scour. Both mitigation sections key in large toe rock to protect the toe zone of the embankment from erosion and scour which should provide long-term stability to the reconstructed slope.

One other key component for permanent design is to utilize an aggregate filter where riprap and coarse rock is in contact with finer grained soil deposits of sand and sandy silt. Both sections are shown on the plans to have an aggregate filter layer consisting of 1 foot of Quarry Spalls and 0.5 feet of Permeable Ballast. In our opinion the aggregate filter layer is critical to both mitigation sections to prevent soil movement and particle loss between the finer grained native soils and coarser toe and Class B rock. In addition, the filter layer may help to prevent the build up of embankment pore pressures.

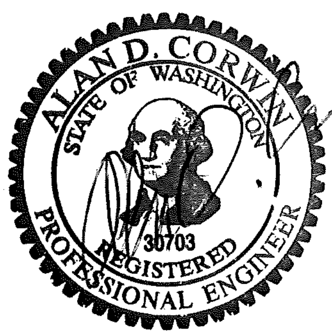
ReSSA (3.0), developed by ADAMA Engineering, Inc., was used to verify the proposed reinforced slope design in accordance with current Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) standard requirements. Based on our analysis, the minimum embedment would be 0.8H feet (H = height of slope) for a geogrid with a minimum long-term tensile strength of 2230 lb/ft. As shown on the plans, the maximum recommended vertical spacing between successive geogrid layers will be 1 foot.

## 5.0 CONTINUING GEOTECHNICAL SERVICES

As the design develops, when needed, we are available to provide additional geotechnical design and construction recommendations for specific aspects of the project.

We appreciate the opportunity to have been of service on this project and trust this report addresses your current needs. Please call Alan Corwin at (206) 477-1853 or Doug Walters at (206) 477-2112, should you have any questions, concerns, or if we may be of further assistance.

Respectfully Submitted,
King County Materials Laboratory




4/29/19

Alan D. Corwin, P.E.
King County Materials Engineer

## 6.0 REFERENCES


ADAMA Engineering, Inc. *Reinforced Slope Stability Analysis Program* ReSSA (3.0), 2001-2012, Version 3.2012.12.41

American Association of State Highway & Transportation Officials (AASHTO), 2017, *LRFD Bridge Design Specifications,* 8th Edition, November 2017

ASTM Standards, Volume 04.08, *ASTM 1586-99 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils,* 2008.

Bethel, John, *An Overview of the Geology and Geomorphology of the Snoqualmie River Watershed*, Prepared for King County Water and Land Resources Division Snoqualmie Watershed Team, April 2004

Clover Associates, *Galena Slope Stability System Software Program, Version 5.02.1.08, 1982 - 2010*

Dragovich, J.D., Littke, H.A., Anderson, M.L., Hartog, Renate, Wessel, G.R., DuFrane, S.A., Walsh, T.J., MacDonald, J.H., Jr., Mangano, J.F., and Cakir, Recep, 2009, *Geologic Map of the Snoqualmie 7.5-minute quadrangle*, King County, Washington: Washington Division of Geology and Earth Resources, Geologic Map GM-75, scale 1:24,000

Garric, Craig, *Reinig Road Revetment Damage Inspection,* Memorandum for King County Water and Land Resources Division, August 2017

King County GIS Center, King County Interactive Mapping Tool; Available on the web at http://www.kingcounty.gov/operations/GIS/Maps/iMAP.aspx.

Washington State Department of Transportation, 1996, Bridge Design Manual, M23-50, 2018.

Washington State Department of Transportation, *Geotechnical Design Manual M46-03.11,* 2015.

Washington State Department of Transportation, Richard Brice, P.E., BridgeLink, Version 1.1.8.0(x64), *Spectra*

Washington State Department of Natural Resources (DNR). *Washington Interactive Geologic Map*. Available on the web at https://fortress.wa.gov/dnr/protectiongis/geology/?Theme=wigm. Accessed July 2017

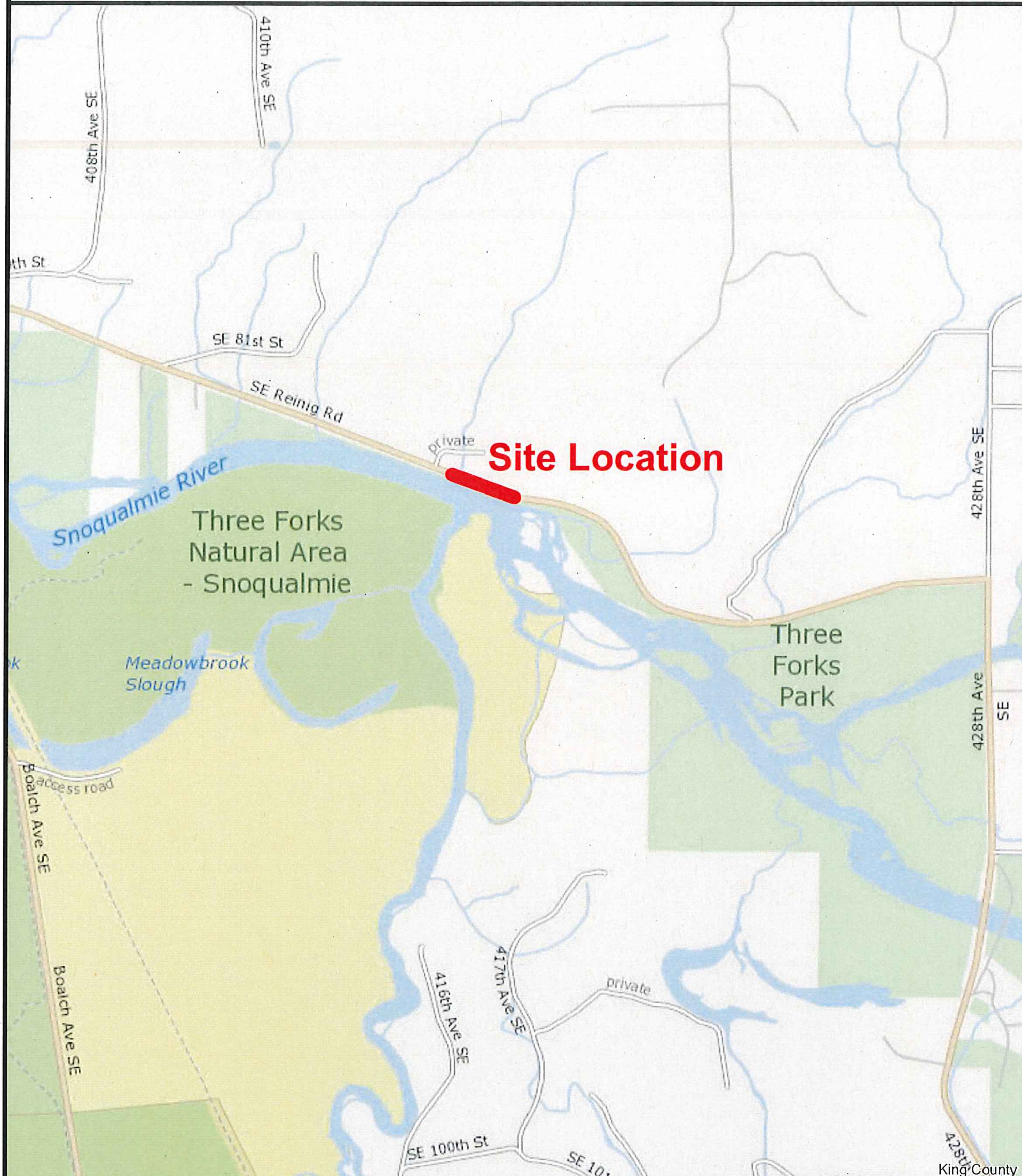
U.S. Army Corps of Engineers (USACE), October 2003, *Slope Stability,* Engineer Manual EM 1110-2-1902.

U.S. Department of Transportation, Federal Highway Administration (FHWA), *Stream Stability at Highway Structures*, Third Edition, FHWA NHI -1-002, March 2001

U.S. Department of Transportation, Federal Highway Administration (FHWA), *LRFD Seismic Analsysis and Deisgn of Transportation Geotechnical Features and Structural Foundations*, Third Edition, FHWA-NHI-032, Aug 2011

United States Geologic Survey (USGS), *The National Geologic Map Database*, Available on the web at http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html.

# Figure 1: Vicinity Map




The information included on this map has been compiled by King County staff from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information. This document is not intended for use as a survey product. King County shall not be liable for any general, special, indirect, incidental, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.

N

King County
GIS Center

Date: 8/30/2017 Notes:

# Figure 2: Boring Locations


The information included on this map has been compiled by King County staff from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information. This document is not intended for use as a survey product. King County shall not be liable for any general, special, indirect, incidental, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.

Date: 6/4/2018 Notes:

N

King County
GIS Center

# APPENDIX A

## Boring Logs

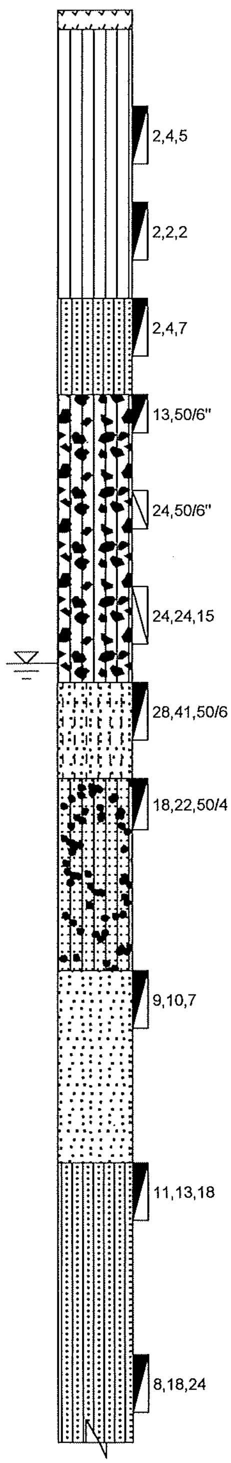
## Laboratory Test Results

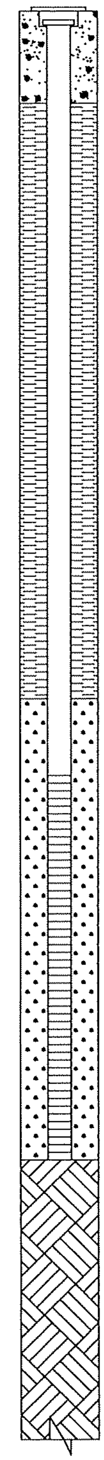
# LOG OF MONITOR WELL INSTALLATION

## WELL NO. B-1

PROJECT: **SE Reinig Road**
BORING LOCATION: **SE Reinig Rd (see location map)**
DRILL METHOD: **Hollow Stem Auger**
DRILLER: **Holocene Drilling**
DEPTH TO - Water: **17'**

DATE: **5/30/2018**
START: **10:45 AM**
FINISH: **2:05 PM**
LOGGER: **Doug Walters**
DATE CHECKED: **N/A**



| ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | USCS | Description | Moist (%) | -200 (%) | Remarks |
|---|---|---|---|---|---|---|
| 0 | | | Grass/Topsoil | | | |
| 420 | 2,4,5 | ML | Dark brown to brown sandy silt, scattered organics, trace roots and gravel, mottled, low plasticity, wet, loose. (fill) | | | 6" sample recovery. |
| 5 | 2,2,2 | | Same-intermixed with red brick debris. | | | 6" sample recovery. |
| 415 | 2,4,7 | SM | Brown to gray silty sand with gravel, trace organics, intermittent iron staining, wet, medium dense. (fill) | 19.1 | 45.1 | 9" sample recovery. |
| 10 | 13,50/6" | GM | Brown silty gravel with sand, numerous cobbles, grain shape generally angular, intermittent iron staining, wet, dense to very dense. (fill) | | | 4" sample recovery. Blow count may be overstated due to presence of cobble. |
| 410 | 24,50/6" | | | | | No sample recovery. |
| 15 | 24,24,15 | | | | | No sample recovery. |
| 405 | 28,41,50/6 | SP-SM | Brown poorly graded sand with silt and gravel to poorly graded gravel with silt and sand, scattered cobbles, saturated, very dense. | 14.4 | 10.2 | 10" sample recovery. Blow count may be overstated due to presence of gravel. |
| 20 | 18,22,50/4 | GP-GM | Brown poorly graded gravel with silt and sand, saturated, very dense. | | | 10" sample recovery. |
| 400 | | | | | | |
| 25 | 9,10,7 | SP | Dark gray poorly graded sand, wet, medium dense. | 20.0 | 3.1 | 14" sample recovery. Water added to auger after sample at 25' to prevent heave. |
| 395 | | | | | | |
| 30 | 11,13,18 | SM | Gray silty sand with interbedded sandy silt, wet, dense. | | | 15" sample recovery. |
| 390 | | | | | | |
| 35 | 8,18,24 | | | 22.1 | 25.9 | 15" sample recovery. |
| 385 | | | | | | |

*Boring B-1 was drilled in the southern shoulder of SE Reinig Road. Groundwater was observed at about 17 feet below the ground surface at the time of drilling. A 2" diameter monitoring well was installed in B-1 and is identified by the WSDOE discrete well tag number BKZ-554.*

PLATE NUMBER **A-1**

# LOG OF MONITOR WELL INSTALLATION
## WELL NO. B-1

PROJECT: **SE Reinig Road**
BORING LOCATION: **SE Reinig Rd (see location map)**
DRILL METHOD: **Hollow Stem Auger**
DRILLER: **Holocene Drilling**
DEPTH TO - Water: **17'**

DATE: **5/30/2018**
START: **10:45 AM**
FINISH: **2:05 PM**
LOGGER: **Doug Walters**
DATE CHECKED: **N/A**

| ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | USCS | Description | Moist (%) | -200 (%) | Remarks | Monitor Well Construction Schematic |
|---|---|---|---|---|---|---|---|
| 40 / 380 | 11,27,38 | | | | | 15" sample recovery. | |
| 45 / 375 | 8,16,18 | ML | Gray sandy silt with interbedded silty sand, no to low plasticity, wet, dense to very dense. | 22.9 | 61.3 | 16" sample recovery. | |
| 50 / 370 | 6,16,18 | | | | | 14" sample recovery. | |
| 55 / 365 | 31,36,50/6 | | | 23.9 | 63.2 | 16" sample recovery. | |
| 60 / 360 | 15,24,29 | | | | | 16" sample recovery. | |
| 65 / 355 | 12,31,35 | ML | Gray silt, no to low plasticity, wet, very dense. | 24.5 | 85.5 | 16" sample recovery. | |
| 70 / 350 | 9,12,14 | ML | Gray sandy silt, no to low plasticity, wet, medium dense. | | | 14" sample recovery. | |

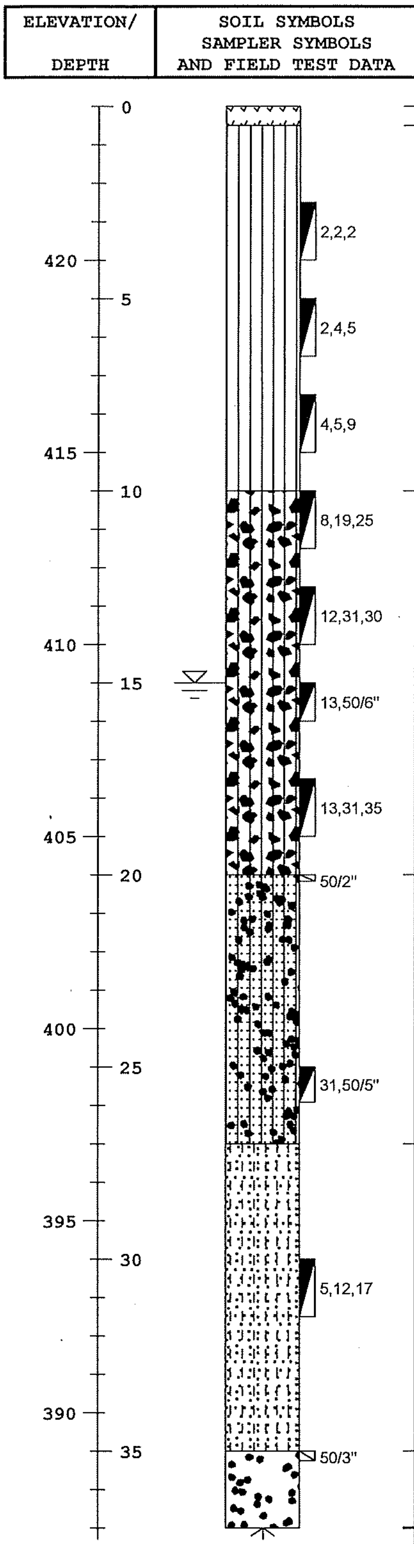
*Boring B-1 was drilled in the southern shoulder of SE Reinig Road. Groundwater was observed at about 17 feet below the ground surface at the time of drilling. A 2" diameter monitoring well was installed in B-1 and is identified by the WSDOE discrete well tag number BKZ-554.*

PLATE NUMBER **A-1**

# LOG OF MONITOR WELL INSTALLATION
## WELL NO. B-2

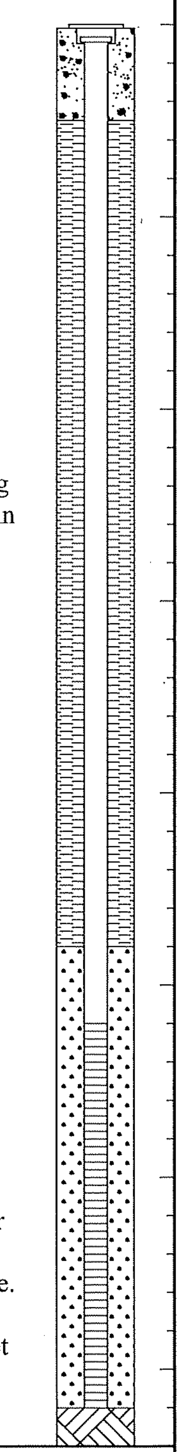
PROJECT: **SE Reinig Road**
BORING LOCATION: **SE Reinig Rd (see location map)**
DRILL METHOD: **Hollow Stem Auger**
DRILLER: **Holocene Drilling**
DEPTH TO - Water: **15'**

DATE: **5/30/2018**
START: **10:45 AM**
FINISH: **2:05 PM**
LOGGER: **Doug Walters**
DATE CHECKED: **N/A**




| USCS | Description | Moist (%) | -200 (%) | Remarks |
|---|---|---|---|---|
| ML | Grass/Topsoil<br>Brown to light gray sandy silt, scattered organics, trace roots and gravel, highly distrubed, intermittent iron staining, low plasticity, wet, loose. (fill)<br>Same-trace wood debris.<br>Same-darker gray with scattered gravel, medium dense. | | | 11" sample recovery.<br>16" sample recovery.<br>15" sample recovery. |
| GM | Gray silty gravel, scattered to numerous cobbles, grain shape generally angular, wet, dense to very dense. (fill) | | | 3" sample recovery. Difficult drilling from 10' to 27' in gravel and cobble.<br>7" sample recovery.<br>5" sample recovery.<br>9" sample recovery. |
| GP-GM | No sample recovery-native?<br>Gray poorly graded gravel with silt and sand, numerous cobbles, fractured rock in sample shoe, wet, very dense. | | | No sample recovery.<br>5" sample recovery. Smooth drilling from 27 to 30'. |
| SP-SM | Gray poorly graded sand with silt, wet, dense. | 18.0 | 10.1 | 13" sample recovery. Water added to auger to prevent heave. Terminated boring at 37 feet due to auger refusal. |
| GP | No sample recovery-gravel and cobble, possible boulder. | | | |

Monitor Well Construction Schematic



*Boring B-2 was drilled in the southern shoulder of SE Reinig Road. Groundwater was observed at about 15 feet below the ground surface at the time of drilling. A 2" diameter monitoring well was installed in B-2 and is identified by the WSDOE discrete well tag number BKZ-553.*

PLATE NUMBER **A-2**

# LOG OF MONITOR WELL INSTALLATION

## WELL NO. B-2

PROJECT: **SE Reinig Road**
BORING LOCATION: **SE Reinig Rd (see location map)**
DRILL METHOD: **Hollow Stem Auger**
DRILLER: **Holocene Drilling**
DEPTH TO - Water: **15'**

DATE: **5/30/2018**
START: **10:45 AM**
FINISH: **2:05 PM**
LOGGER: **Doug Walters**
DATE CHECKED: **N/A**

| ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | USCS | Description | Moist (%) | -200 (%) | Remarks | Monitor Well Construction Schematic |
|---|---|---|---|---|---|---|---|
| 385 | | | | | | | |
| 40 | | | | | | | |
| 380 | | | | | | | |
| 45 | | | | | | | |
| 375 | | | | | | | |
| 50 | | | | | | | |
| 370 | | | | | | | |
| 55 | | | | | | | |
| 365 | | | | | | | |
| 60 | | | | | | | |
| 360 | | | | | | | |
| 65 | | | | | | | |
| 355 | | | | | | | |
| 70 | | | | | | | |
| 350 | | | | | | | |

*Boring B-2 was drilled in the southern shoulder of SE Reinig Road. Groundwater was observed at about 15 feet below the ground surface at the time of drilling. A 2" diameter monitoring well was installed in B-2 and is identified by the WSDOE discrete well tag number BKZ-553.*

# LOG OF BORING

## BORING B-3

PROJECT: **SE Reinig Road**
BORING LOCATION: **SE Reinig Rd (see location map)**
DRILL METHOD: **Hollow Stem Auger**
DRILLER: **Holocene Drilling**
DEPTH TO - Water: **15.5'** Caving: **N/A**

DATE: **5/29/2018**
START: **12:05 PM**
FINISH: **2:14 PM**
LOGGER: **Doug Walters**
DATE CHECKED: **N/A**

| ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | USCS | Description | Moist (%) | -200 (%) | Remarks |
|---|---|---|---|---|---|---|
| 425 / 0 | | | 6" ACP | | | |
| | 8,2,1 | SM | Gray silty sand with gravel, moist to wet, medium dense. (fill) | | | 10" sample recovery. |
| 420 / 5 | 0,2,1 | ML | Brown to light gray sandy silt, scattered intermixed organics, low plasticity, heavy intemittent iron staining, highly disturbed, wet, very loose to loose. (fill) Same-trace charcoal. | | | 15" sample recovery. |
| | 6,8,17 | SP-SM | Gray poorly graded sand with silt and gravel, wet, medium dense to dense. Same-iron stained. | | | 14" sample recovery. |
| 415 / 10 | 12,15,16 | | | | | 5" sample recovery. |
| | 10,12,16 | ML | Gray sandy silt with interbedded silty sand, no to low plasticity, minor intermittent iron staining, wet, medium dense. | 23.0 | 53.5 | 14" sample recovery. |
| 410 / 15 | 10,11,16 | SM | Gray silty sand with interbedded layers of sandy silt, wet, medium dense to dense. | | | 18" sample recovery. |
| | 9,13,15 | | | | | 14" sample recovery. |
| 405 / 20 | 10,14,17 | | | | | 17" sample recovery. |
| 400 / 25 | 9,18,21 | | | 24.3 | 20.8 | 15" sample recovery. |
| 395 / 30 | 8,14,21 | | | | | 17" sample recovery. |
| 390 / 35 | 15,20,28 | | | 26.2 | 30.9 | 14" sample recovery. |

*Boring B-3 was drilled in the center of the west bound driving lane of SE Reinig Road. Groundwater was estimated to be about 15.5 feet below the ground surface at the time of drilling.*

# LOG OF BORING
## BORING B-3
(continued)

| ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | USCS | Description | Moist (%) | -200 (%) | Remarks |
|---|---|---|---|---|---|---|
| 385 — 40 | 14,18,38 | ML | Gray sandy silt with interbedded layers of silt and silty sand, no to low plasticity, wet, dense to very dense. | | | 18" sample recovery. Blow count may be overstated due to slight heave. |
| 380 — 45 | 10,18,32 | | | 21.0 | 63.3 | 16" sample recovery. |
| 375 — 50 | 13,28,32 | | | | | 16" sample recovery. |
| 370 — 55 | | | | | | |
| 365 — 60 | | | | | | |
| 360 — 65 | | | | | | |
| 355 — 70 | | | | | | |
| 350 — 75 | | | | | | |
| 345 — 80 | | | | | | |

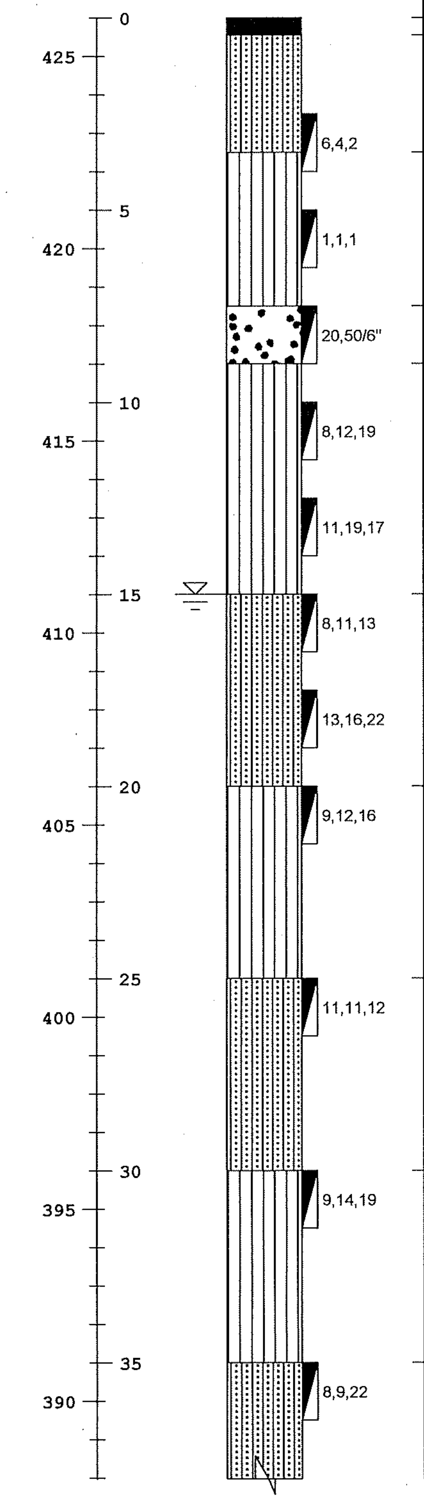
# LOG OF BORING

## BORING B-4

PROJECT: **SE Reinig Road**
BORING LOCATION: **SE Reinig Rd (see location map)**
DRILL METHOD: **Hollow Stem Auger**
DRILLER: **Holocene Drilling**
DEPTH TO - Water: **15'** Caving: **N/A**

DATE: **5/29/2018**
START: **8:30 AM**
FINISH: **11:15 AM**
LOGGER: **Doug Walters**
DATE CHECKED: **N/A**

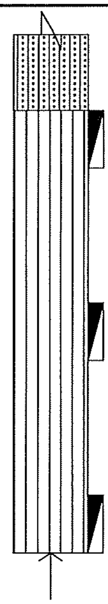
ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA




| USCS | Description | Moist (%) | -200 (%) | Remarks |
|---|---|---|---|---|
| | 5.5" ACP | | | |
| SM | Brown gray silty sand with gravel, moist, medium dense. (fill) | | | 6" sample recovery. |
| ML | Dark brown to light gray sandy silt, scattered intermixed organics, low plasticity, highly disturbed, wet, very loose to loose. (fill) | | | 14" sample recovery. |
| GP | Gray with greenish tint poorly graded gravel, minor seepage zone, minimal recovery, saturated, very dense. (fill) | | | 2" sample recovery. Blow count may be overstated due to presence of gravel. |
| ML | Dark gray silt to sandy silt, visible partings of fine sand, low plasticity, disturbed, wet, hard. | 20.0 | 97.6 | 18" sample recovery. 17" sample recovery. |
| SM | Gray silty sand with interbedded layers of sandy silt, saturated, medium dense to dense. | | | 15" sample recovery. 16" sample recovery. |
| ML | Gray sandy silt with interbedded layers of silty sand, no to low plasticity, wet, medium dense to dense. | 23.6 | 52.5 | 18" sample recovery. |
| SM | Gray silty sand with interbedded layers of sandy silt, saturated, medium dense to dense. | | | 16" sample recovery. |
| ML | Gray sandy silt with interbedded layers of silty sand, no to low plasticity, wet, medium dense to dense. | 23.7 | 64.3 | 18" sample recovery. |
| SM | Gray silty sand with interbedded layers of sandy silt, saturated, dense. | | | 18" sample recovery. |

*Boring B-4 was drilled in the center of the west bound driving lane of SE Reinig Road. Groundwater was estimated to be about 15 feet below the ground surface at the time of drilling.*

# LOG OF BORING
## BORING B-4
(continued)



| ELEVATION/ DEPTH | SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA | USCS | Description | Moist (%) | -200 (%) | Remarks |
|---|---|---|---|---|---|---|
| 40 / 385 | 11,16,24 | ML | Gray sandy silt with interbedded layers of silty sand, no to low plasticity, wet, medium dense to dense. | 26.0 | 64.4 | 18" sample recovery. Blow count may be overstated due to slight heave. |
| 45 / 380 | 9,11,20 | | | | | 18" sample recovery. |
| 50 / 375 | 7,15,25 | | | | | 18" sample recovery. |
| 55 / 370 | | | | | | |
| 60 / 365 | | | | | | |
| 65 / 360 | | | | | | |
| 70 / 355 | | | | | | |
| 75 / 350 | | | | | | |
| 80 / 345 | | | | | | |

# KEY TO SYMBOLS

Symbol Description

Strata symbols

- Topsoil
- Silt
- Silty sand
- Silty gravel
- Poorly graded sand with silt
- Poorly graded gravel with silt
- Poorly graded sand
- Poorly graded gravel
- Paving

Misc. Symbols

- Water table during drilling
- Drill rejection
- Boring continues

Symbol Description

Soil Samplers

- Standard penetration test
- No recovery

Monitor Well Details

- flush-mount cover
- recessed cover set in concrete
- concrete seal
- bentonite pellets
- silica sand, blank PVC
- slotted pipe w/ sand
- no pipe, filler material

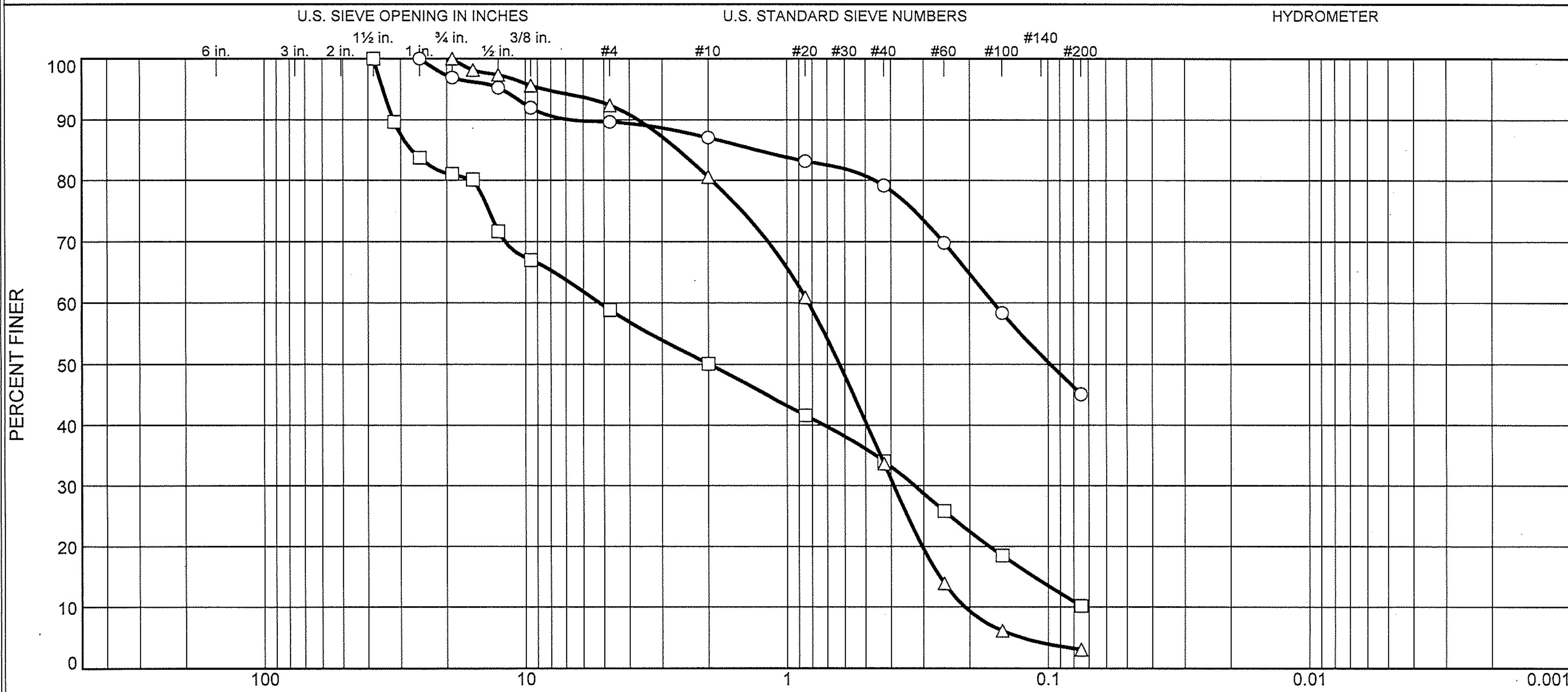
Notes:

1. Four borings, B-1 through B-4, were drilled on May 29th and 30th using a Diedrich D-50 track mounted drill rig with 3-1/4" I.D. continuous flight hollow stem auger.

2. Boring elevations were estimated from preliminary plans.

3. These logs are subject to the limitations, conclusions, and recommendations in this report.

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 3.1 | 7.3 | 2.6 | 7.8 | 34.1 | 45.1 | |
| □ | 0.0 | 19.0 | 22.2 | 8.7 | 16.1 | 23.8 | 10.2 | |
| △ | 0.0 | 0.0 | 7.6 | 11.8 | 47.0 | 30.5 | 3.1 | |

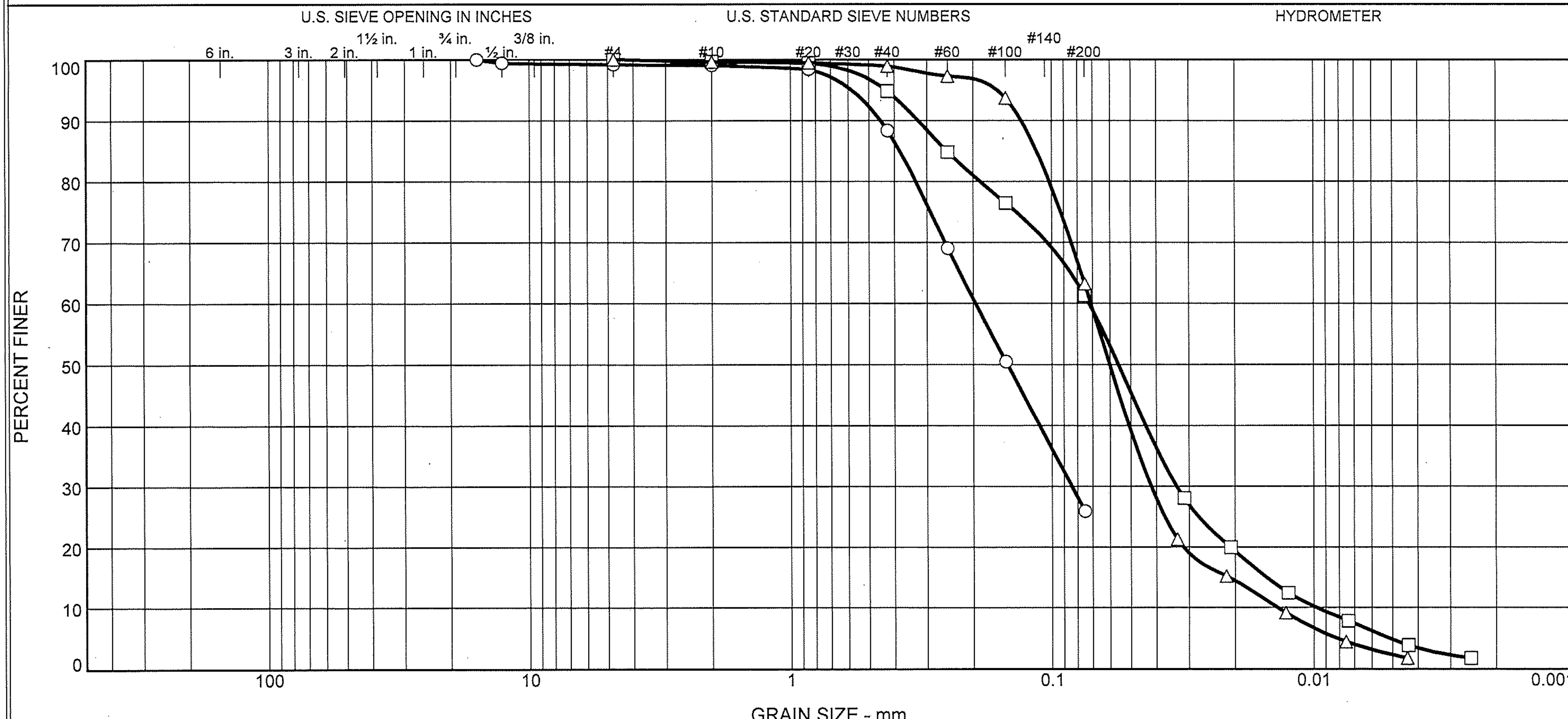
| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | B-1 | KC-18-204 | 7.5'-9.0' | 5-30-2018 | SM | Silty Sand | 19.1 | | |
| □ | B-1 | KC-18-205 | 17.5'-19.0' | 5-30-2018 | SP-SM | Poorly Graded Sand with Silt and Gravel | 14.4 | | |
| △ | B-1 | KC-18-206 | 25.0'-26.5 | 5-30-2018 | SP | Poorly Graded Sand | 20.0 | | |

Client King County DNRP
Project Reinig Road
Project No. 1132628
Figure A-5

**KING COUNTY**

**MATERIALS LABORATORY**

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.8 | 0.2 | 10.6 | 62.5 | 25.9 | |
| □ | 0.0 | 0.0 | 0.0 | 0.4 | 4.8 | 33.5 | 56.6 | 4.7 |
| △ | 0.0 | 0.0 | 0.0 | 0.4 | 0.7 | 35.7 | 60.9 | 2.3 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | B-1 | KC-18-207 | 35.0-36.5 | 5-30-2018 | SM | Silty Sand | 22.1 | | |
| □ | B-1 | KC-18-208 | 45.0'-46.5' | 5-30-2018 | ML | Sandy Silt | 22.9 | | |
| △ | B-1 | KC-18-209 | 55.0'-56.5 | 5-30-2018 | ML | Sandy Silt | 23.9 | | |

Client King County DNRP

Project Reinig Road

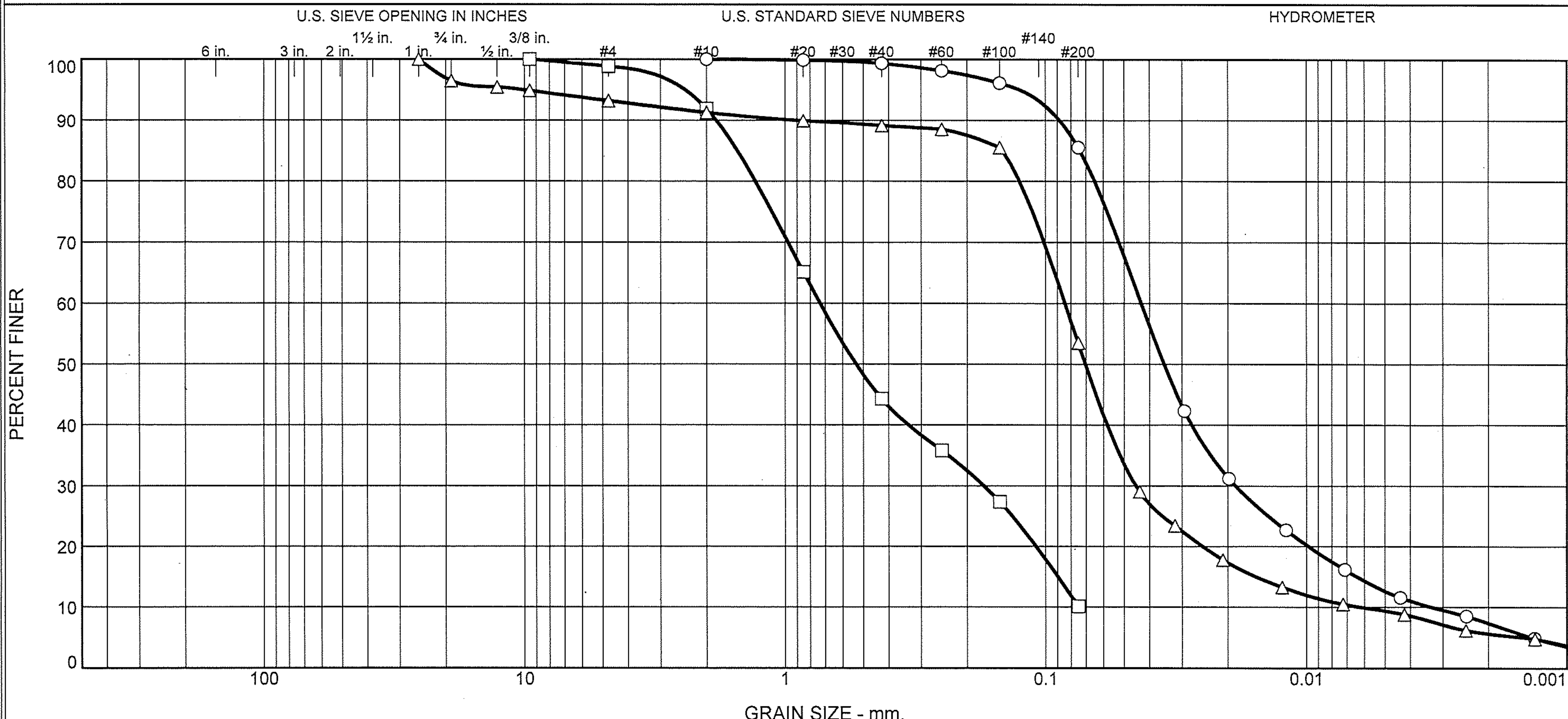
Project No. 1132628

Figure A-6

**KING COUNTY**

**MATERIALS LABORATORY**

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 13.8 | 72.9 | 12.6 |
| □ | 0.0 | 0.0 | 1.2 | 6.9 | 47.6 | 34.2 | 10.1 | |
| △ | 0.0 | 3.6 | 3.2 | 1.9 | 2.2 | 35.6 | 44.1 | 9.4 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | B-1 | KC-18-210 | 65.0'-66.5' | 5-30-2018 | ML | Silt | 24.5 | | |
| □ | B-2 | KC-18-211 | 30.0'-31.5 | 5-30-2018 | SP-SM | Poorly Graded Sand with Silt | 18.0 | | |
| △ | B-3 | KC-18-212 | 12.5'-14.0' | 5-29-2018 | ML | Sandy Silt | 23.0 | | |

Client King County DNRP

Project Reinig Road

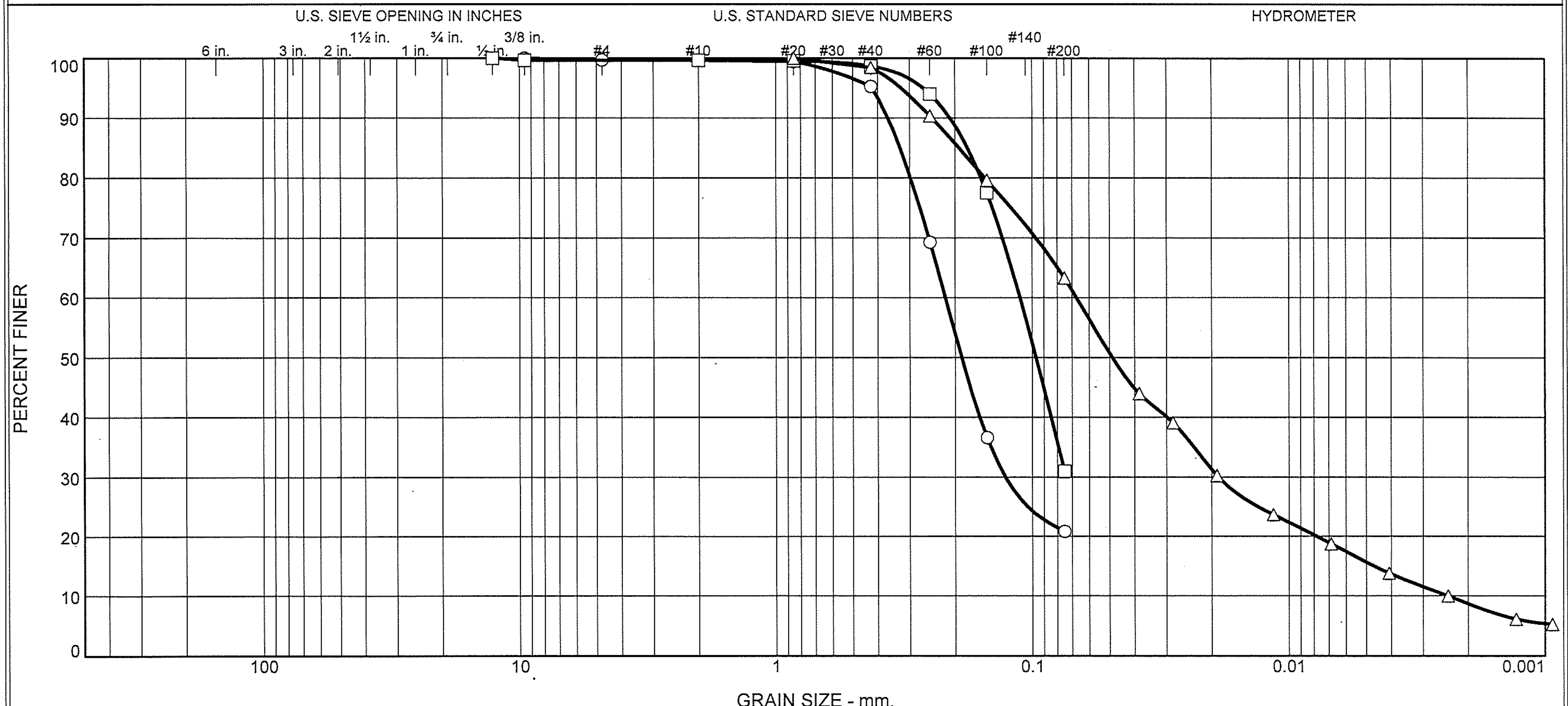
Project No. 1132628

Figure A-7

**KING COUNTY**

**MATERIALS LABORATORY**

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.3 | 0.1 | 4.4 | 74.4 | 20.8 | |
| □ | 0.0 | 0.0 | 0.4 | 0.0 | 0.9 | 67.8 | 30.9 | |
| △ | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 35.1 | 47.7 | 15.6 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | B-3 | KC-18-213 | 25.0'-26.5' | 5-29-2018 | SM | Silty Sand | 24.3 | | |
| □ | B-3 | KC-18-214 | 35.0-36.5' | 5-29-2018 | SM | Silty Sand | 26.2 | | |
| △ | B-3 | KC-18-215 | 45.0'-46.5' | 3-29-2018 | ML | Sandy Silt | 21.0 | | |

Client King County DNRP

Project Reinig Road

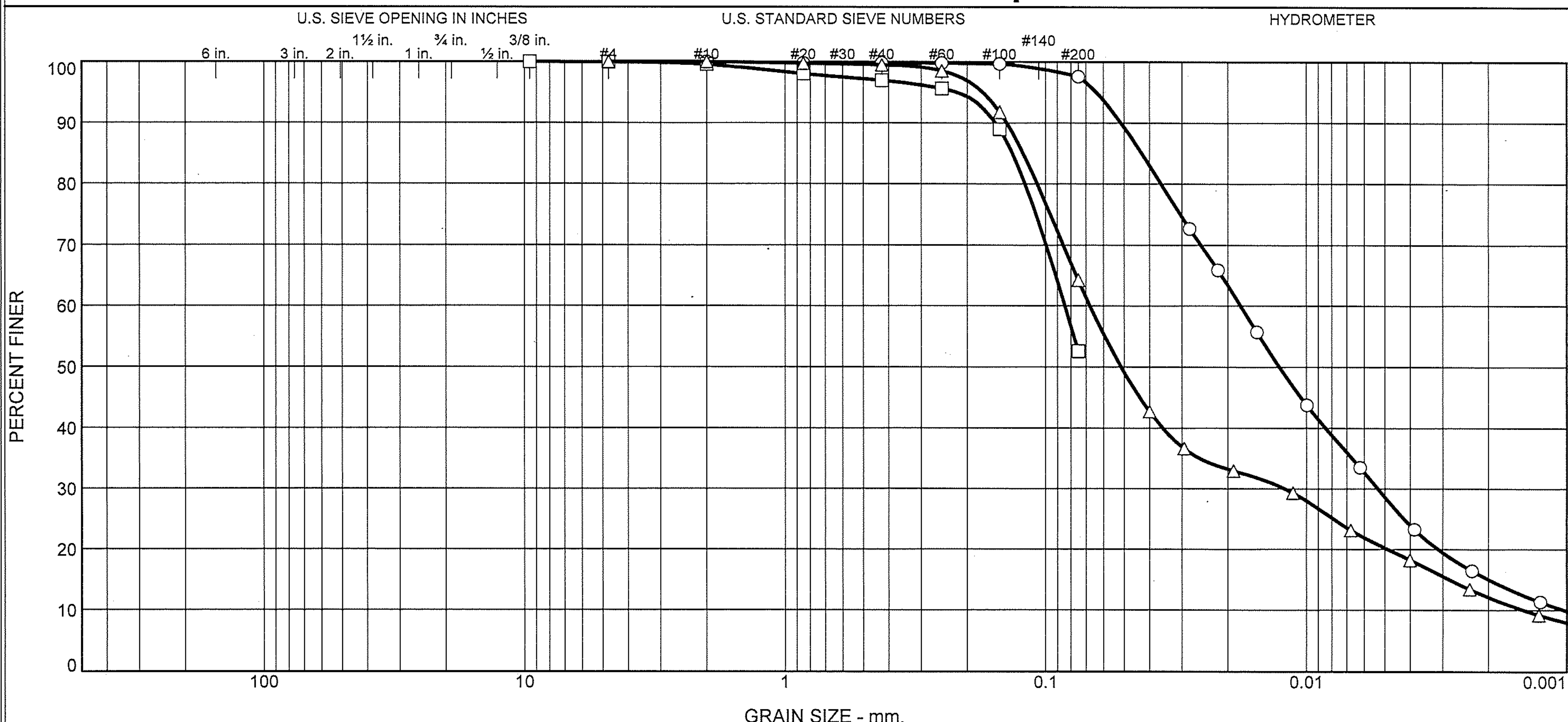
Project No. 1132628

Figure A-8

**KING COUNTY**

**MATERIALS LABORATORY**

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 2.2 | 69.0 | 28.6 |
| □ | 0.0 | 0.0 | 0.1 | 0.4 | 2.6 | 44.4 | 52.5 | |
| △ | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 35.2 | 44.1 | 20.2 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | B-4 | KC-18-216 | 10.0'-11.5' | 5-29-18 | ML | Silt | 20.0 | | |
| □ | B-4 | KC-18-217 | 20.0'-21.5' | 5-29-2018 | ML | Sandy Silt | 23.6 | | |
| △ | B-4 | KC-18-218 | 30.0'-31.5' | 5-29-2018 | ML | Sandy Silt | 23.7 | | |

Client King County DNRP

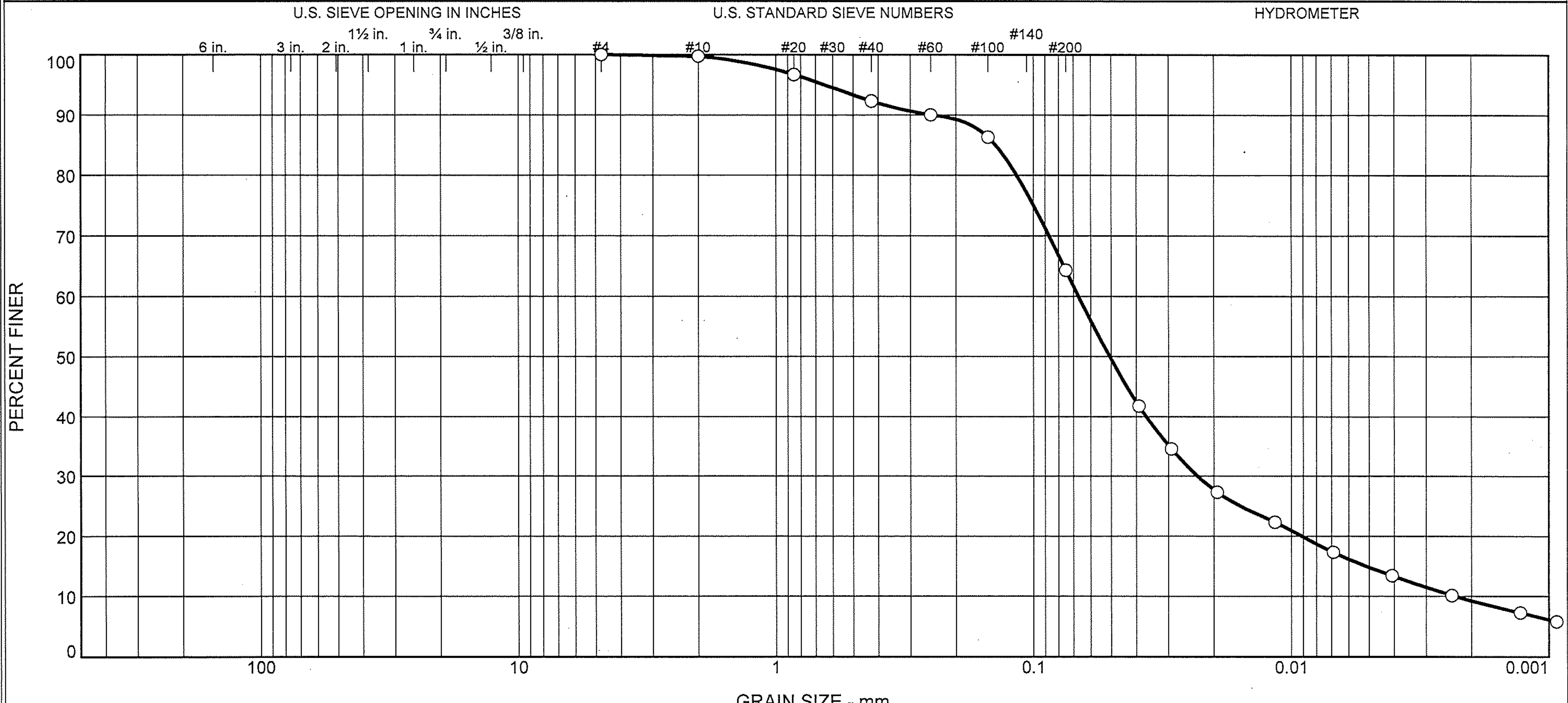
Project Reinig Road

Project No. 1132628 Figure A-9

**KING COUNTY**

**MATERIALS LABORATORY**

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.3 | 7.4 | 27.9 | 49.6 | 14.8 |

| | Source | Sample # | Depth/Elev. | Date Sampled | USCS | Material Description | NM % | LL | PL |
|---|---|---|---|---|---|---|---|---|---|
| ○ | B-4 | KC-18-219 | 40.0'-41.5' | 5-29-2018 | ML | Sandy Silt | 26.0 | | |

Client King County DNRP

Project Reinig Road

Project No. 1132628

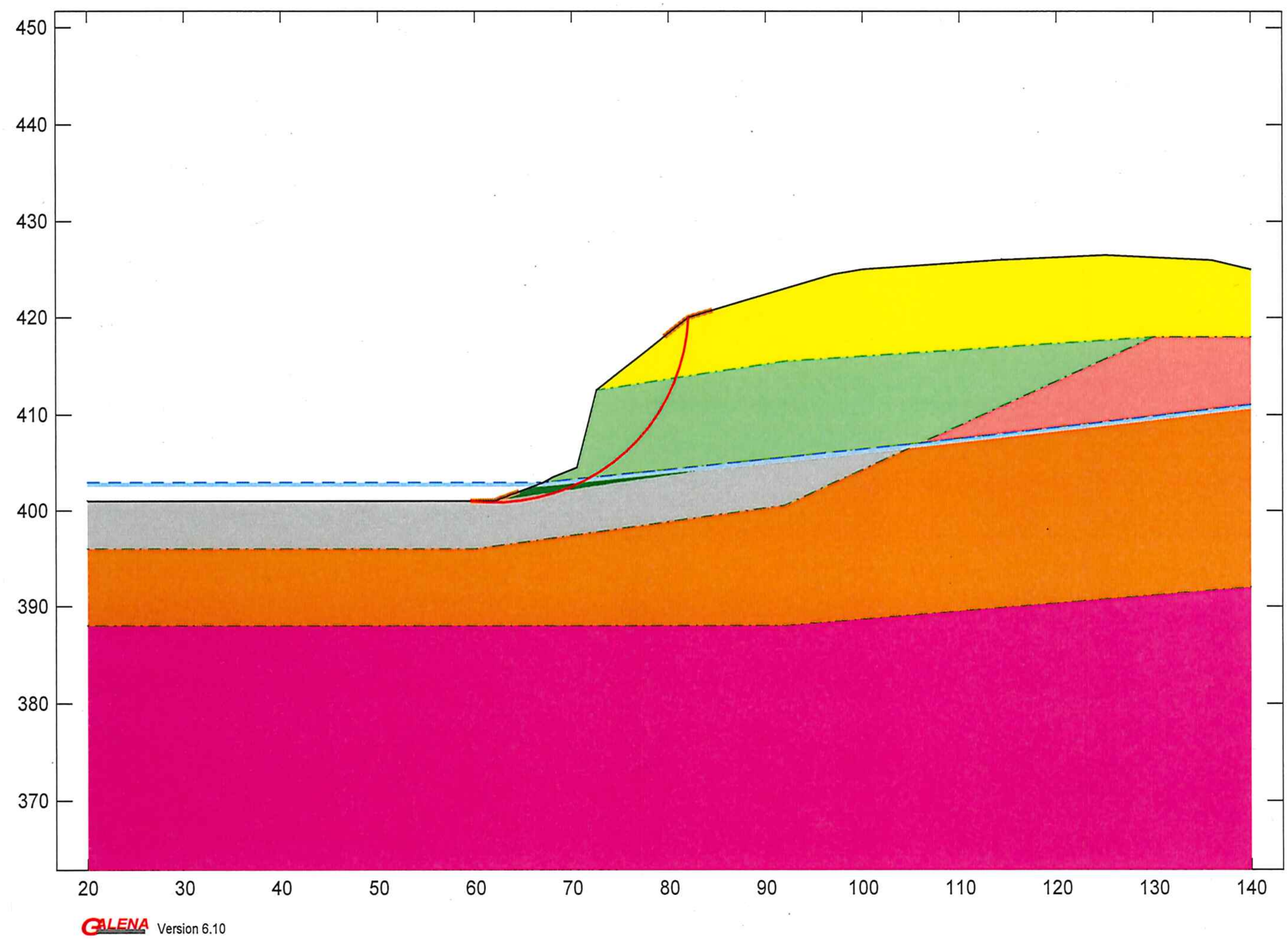
Figure A-10

**KING COUNTY**

**MATERIALS LABORATORY**

# APPENDIX B

## Slope Stability Analyses Critical Failure Drawings




## Material Keys

- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel
- Dense Silty Gravel (bwt)
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand

## Analysis 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

## Results

*Critical Factor of Safety:* 1.06

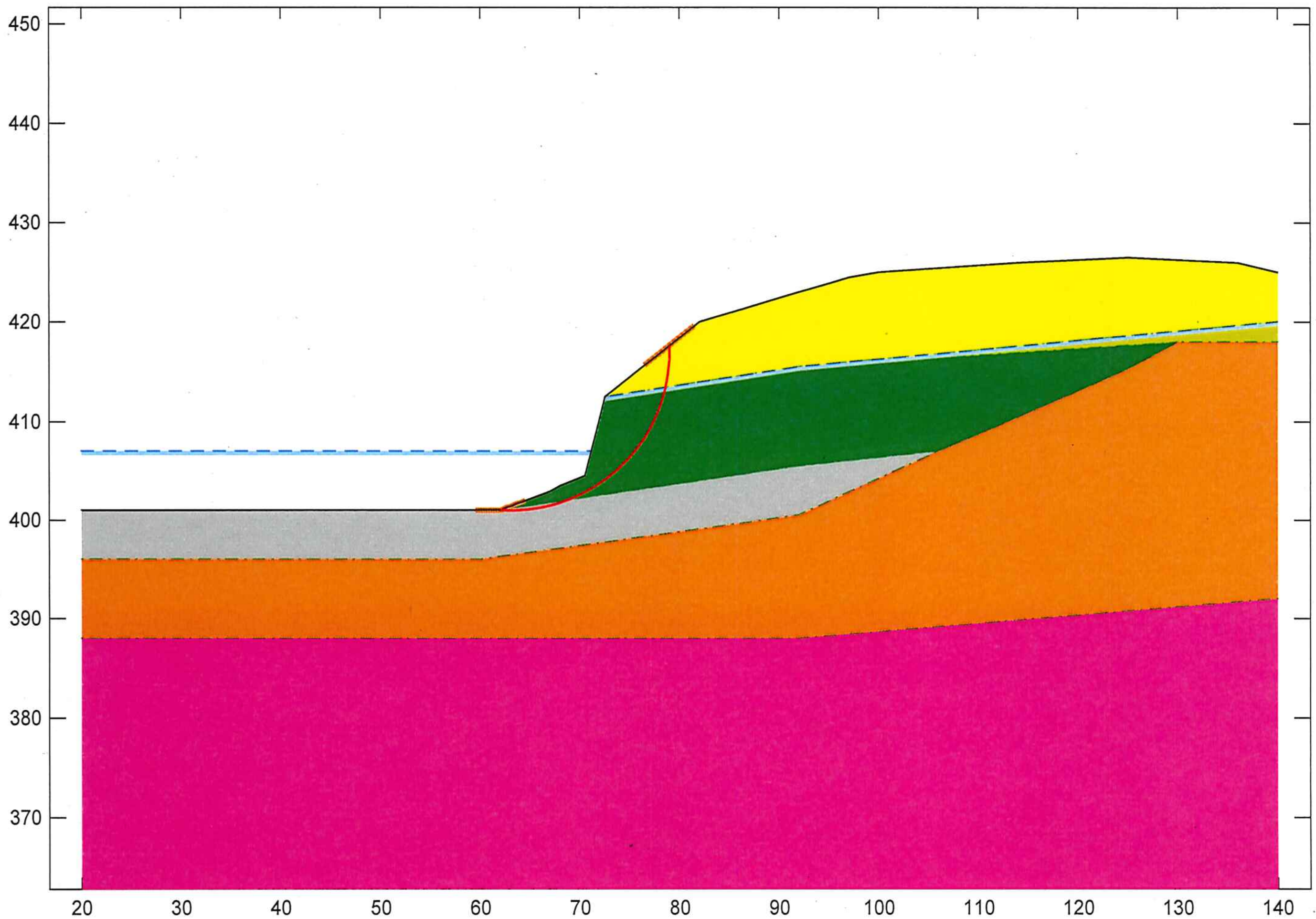
*Edited:* 1 Mar 2019 *Processed:*1 Mar 2019

*Project* Reinig Road: Existing Condition Section C-C
Low Flow Water Elevation 402.9

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Low Flow Existing Final.gmf

*Figure:* B-1

**King County Materials Laboratory**




GALENA Version 6.10

## *Material Keys*

- Loose Sandy Silt/Silty Sand (fill)
- Loose Sandy Silt/Silty Sand (fill-bwt)
- Dense Silty Gravel (bwt)
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand

*Analysis* 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

*Results*

*Critical Factor of Safety:* 0.62

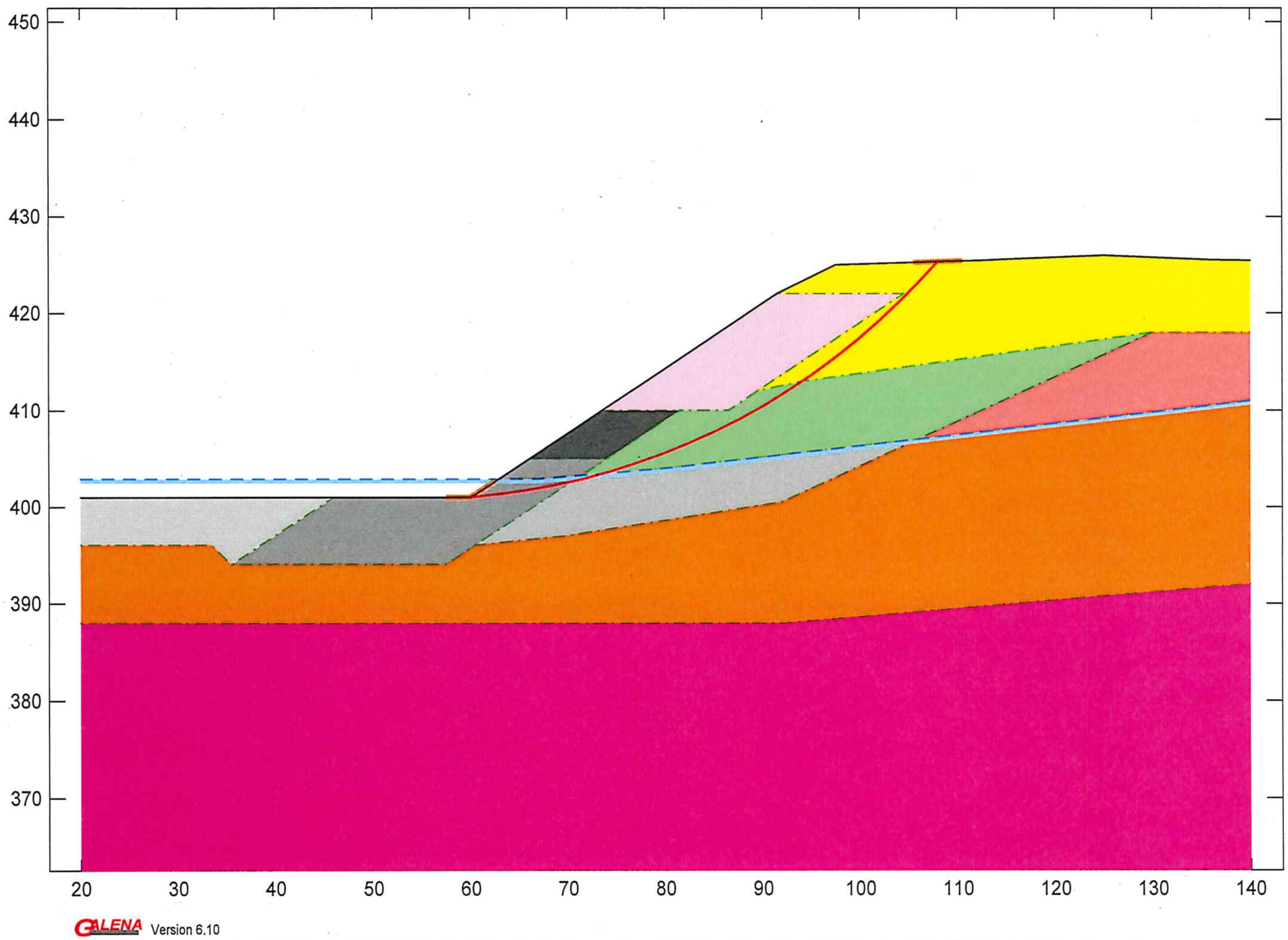
*Edited:* 1 Mar 2019 *Processed:* 1 Mar 2019

*Project* Reinig Road: Existing Condition Section C-C
Drawdown

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Existing Slope Drawdown Final.gmf

*Figure:* B-2

**King County Materials Laboratory**




## Material Keys

- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel (fill)
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand
- Geogrid Wrap w/ Gravel Borrow
- Riprap
- Medium well graded gravel
- Class B Rock

*Analysis* 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

*Results*

*Critical Factor of Safety:* 1.57

*Edited:* 1 Mar 2019 *Processed:* 1 Mar 2019

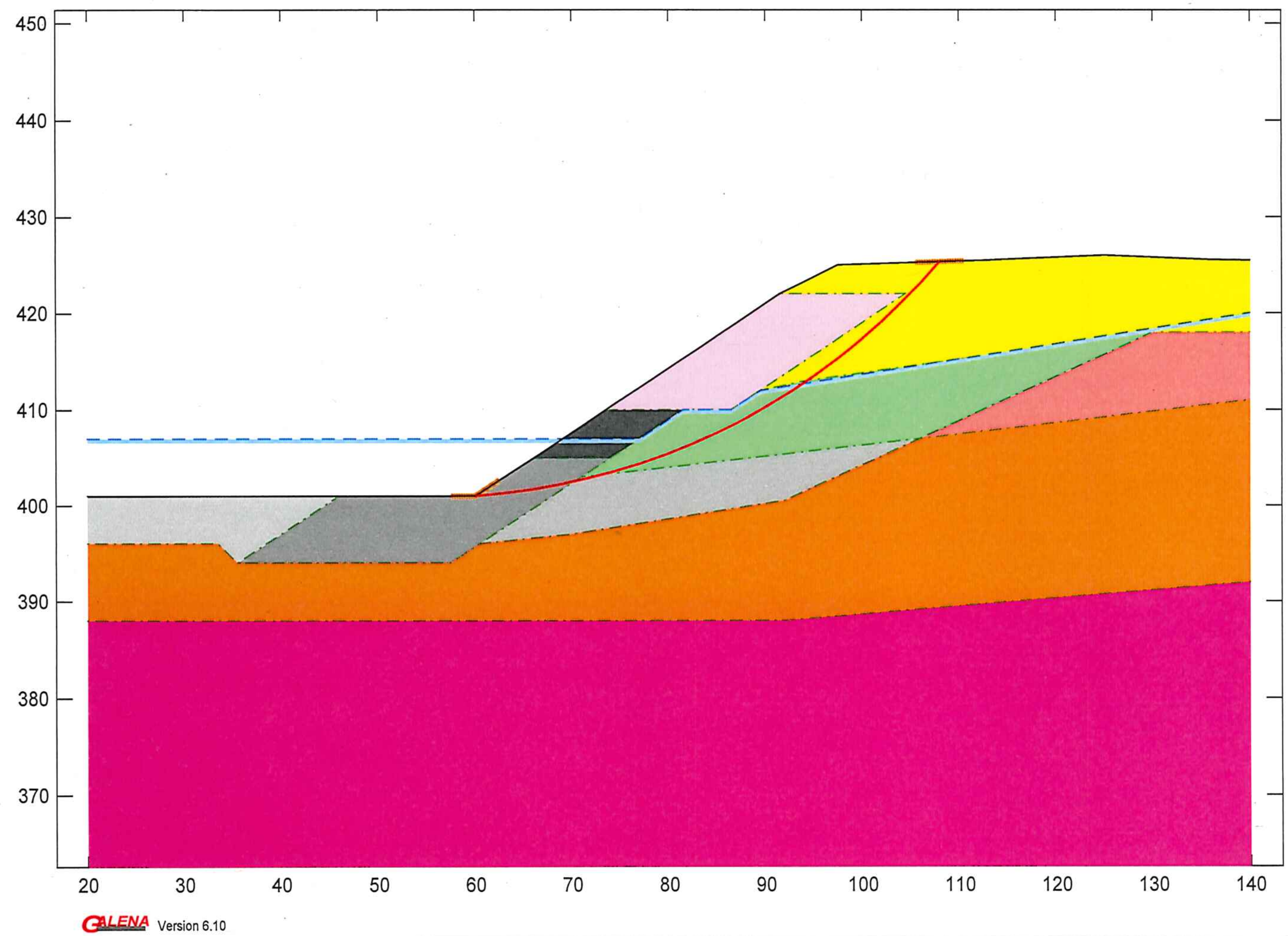
*Project* Reinig Road:Section C-C

1.5H:1V Rock Slope/Reinforced Slope Low Flow

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Low Flow Reinforced Slope Final.gmf

*Figure:* B-3

**King County Materials Laboratory**




*Material Keys*

- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel (fill)
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand
- Geogrid Wrap w/ Gravel Borrow
- Riprap
- Medium well graded gravel
- Class B Rock

*Analysis* 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

*Results*

*Critical Factor of Safety:* 1.42

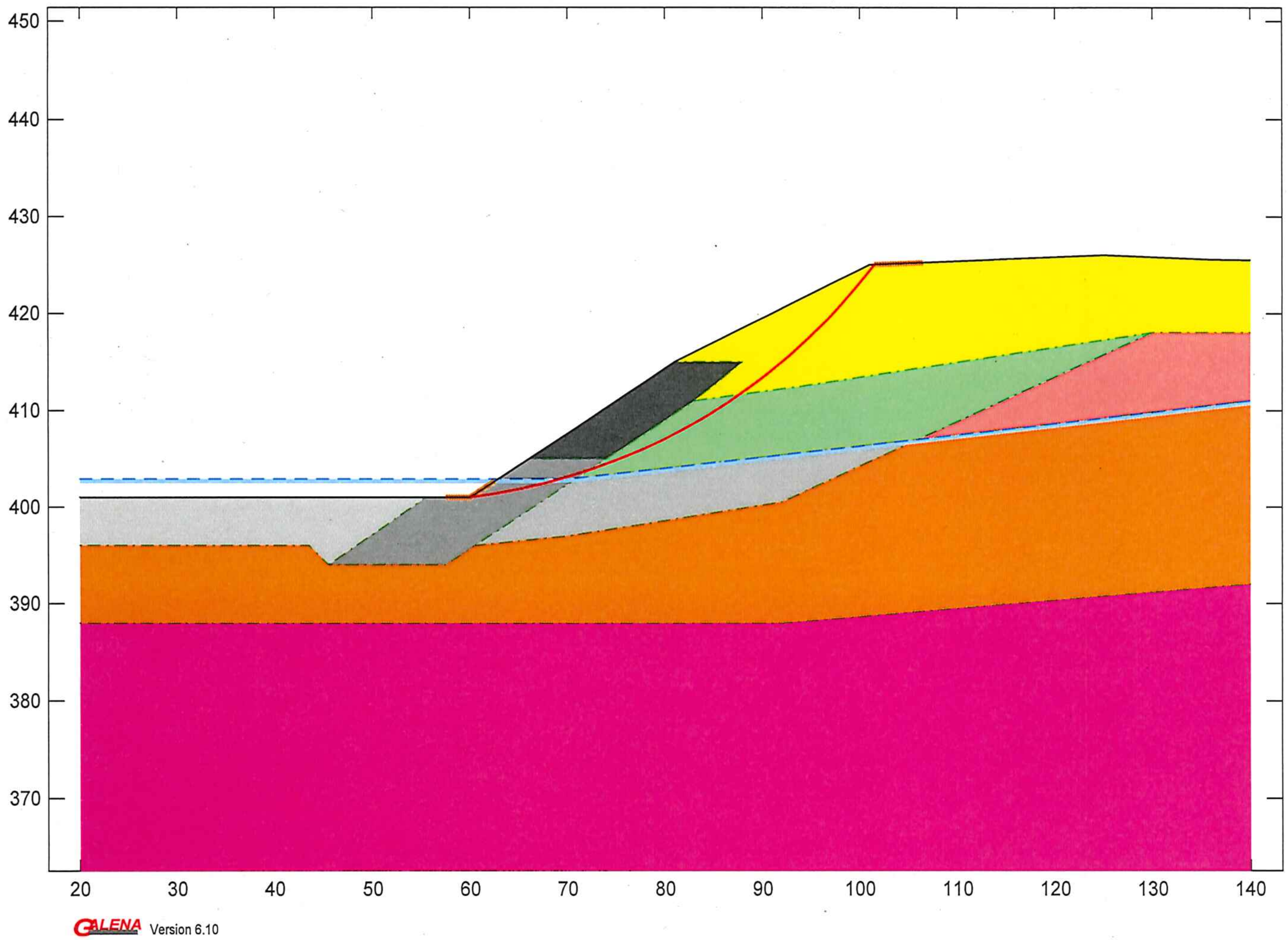
*Edited:* 1 Mar 2019 *Processed:*1 Mar 2019

*Project* Reinig Road: Slope Section C-C
1.5H:1V Rock Slope/Reinforced Slope Drawdown

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Drawdown Reinforced Slope Final.gmf

*Figure:* B-4

King County Materials Laboratory




*Material Keys*
- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand
- Riprap
- Medium well graded gravel
- Class B Rock

*Analysis* 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

*Results*

*Critical Factor of Safety:* 1.54

*Edited:* 1 Mar 2019 *Processed:*1 Mar 2019

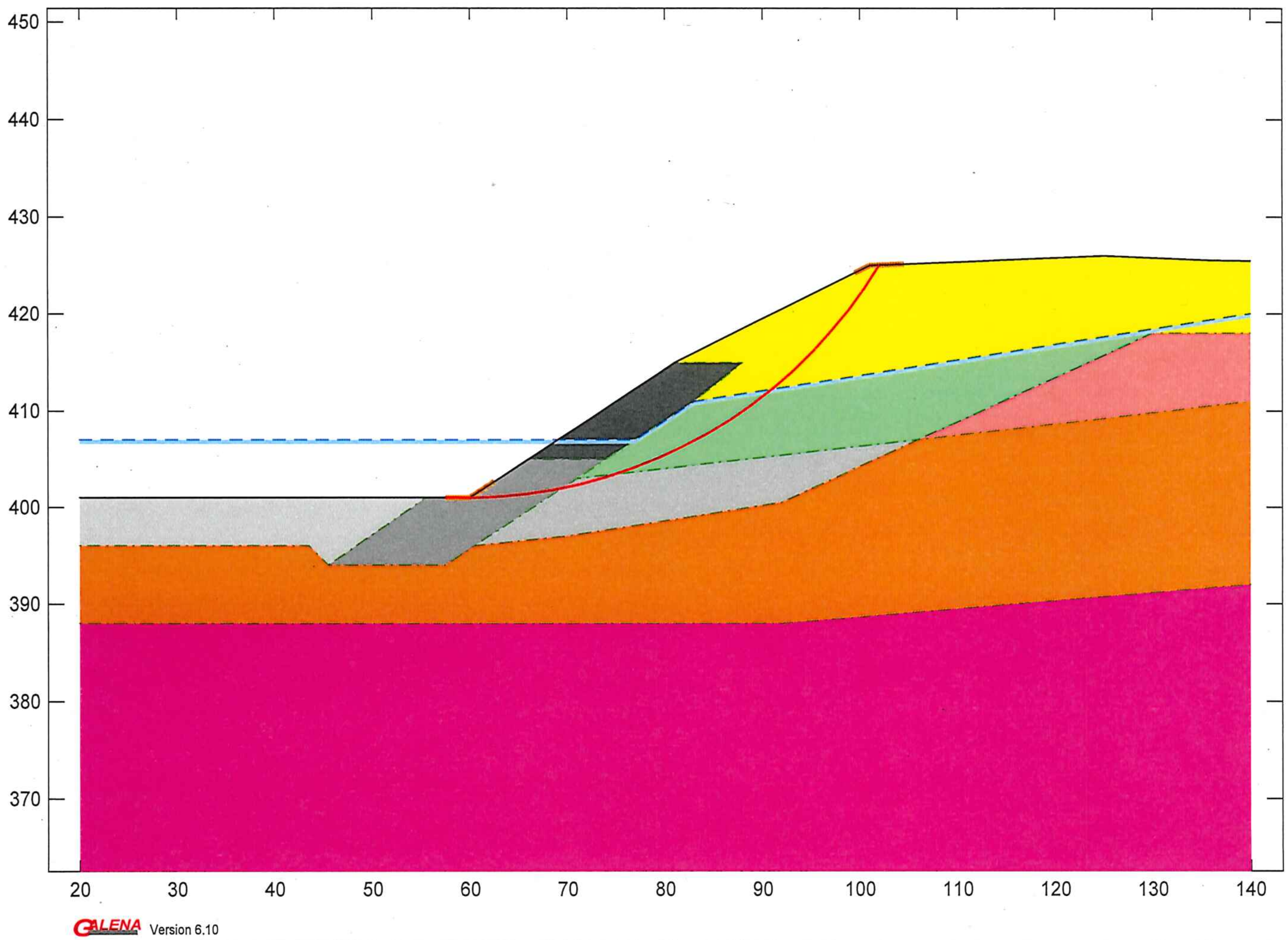
*Project* Reinig Road: Slope Section C-C

1.5H:1V Rock Slope/2H:1V Upper Soil Slope Low Flow

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Rock Slope Low Flow Final.gmf

*Figure:* B-5

**King County Materials Laboratory**




## Material Keys

- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand
- Riprap
- Medium well graded gravel
- Class B Rock

*Analysis* 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

*Results*

*Critical Factor of Safety:* 1.37

*Edited:* 1 Mar 2019 *Processed:* 1 Mar 2019

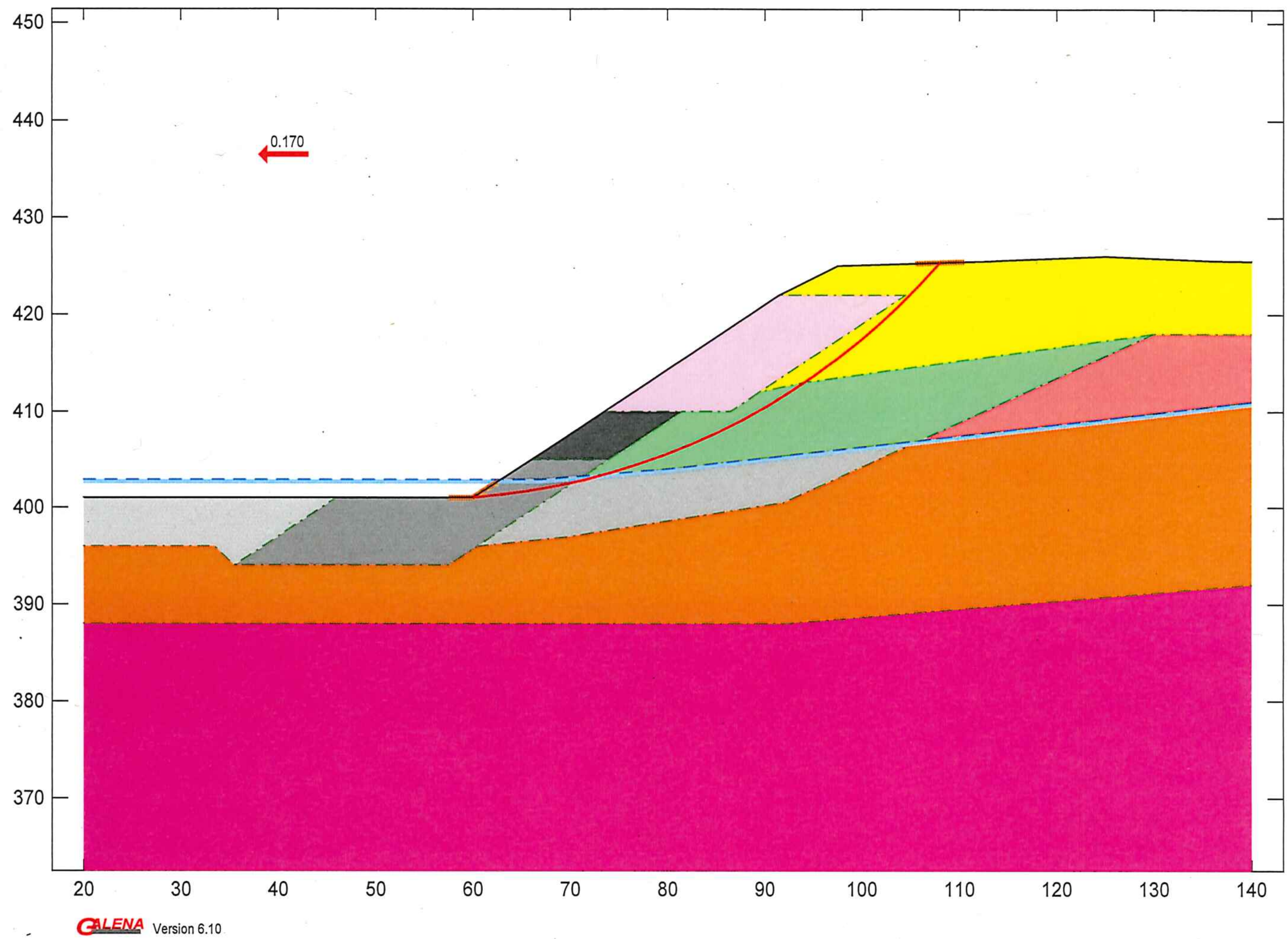
*Project* Reinig Road: Slope Section C-C

1.5H:1V Rock Slope/2H:1V Upper Soil Slope Drawdown

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Rock Slope Final Drawdown.gmf

*Figure:* Figure B-6

**King County Materials Laboratory**




*Material Keys*

- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel (fill)
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand
- Geogrid Wrap w/ Gravel Borrow
- Riprap
- Medium well graded gravel
- Class B Rock

*Analysis* 1
Multiple Stability Analysis
*Method:* Bishop Simplified
*Surface:* Circular

*Results*
*Critical Factor of Safety:* 1.11

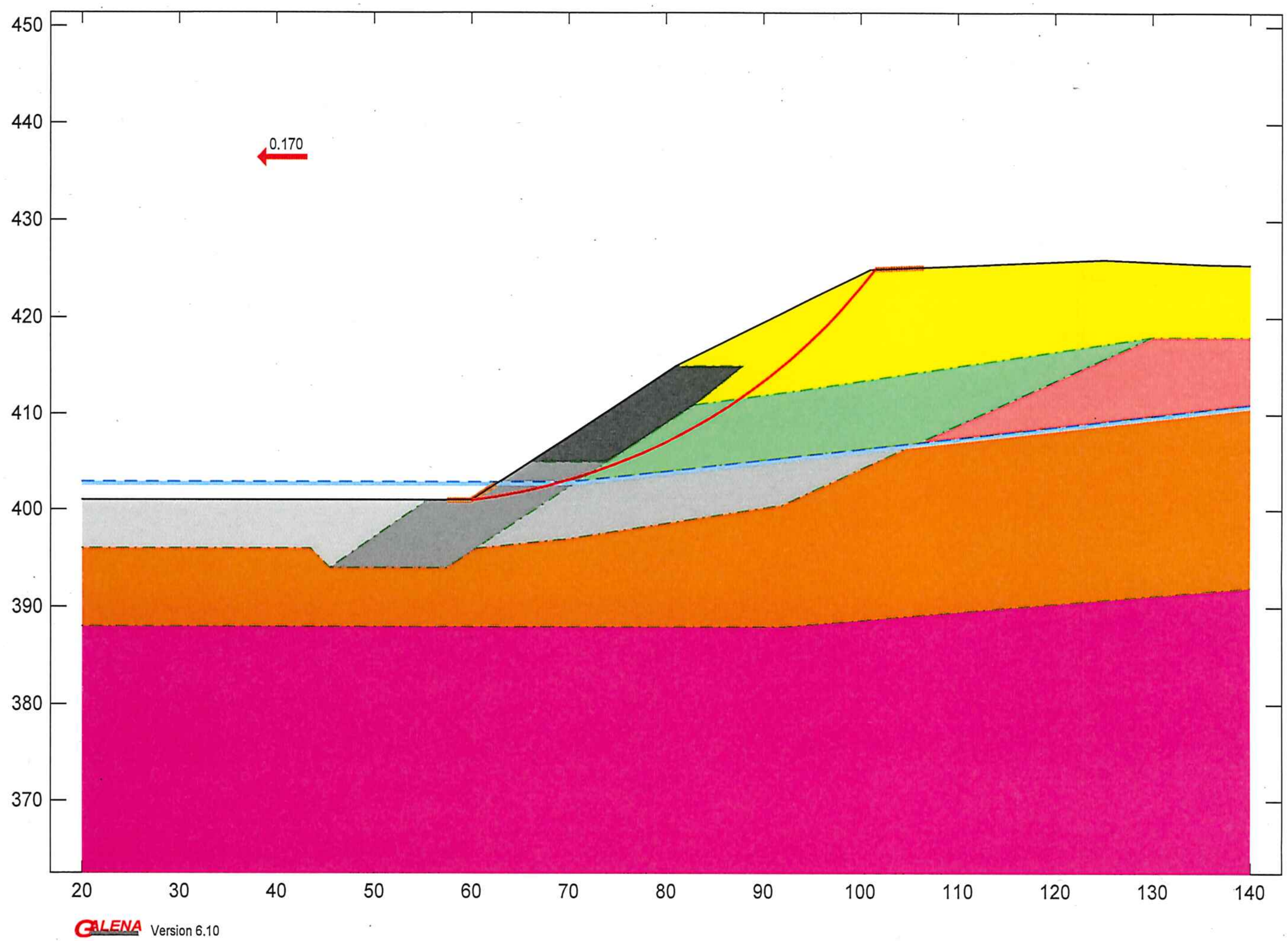
*Edited:* 29 Apr 2019 *Processed* 29 Apr 2019

*Project* Reinig Road:Section C-C
1.5H:1V Rock Slope/Reinforced Slope Low Flow (Seismic)

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Low Flow Reinforced Slope Final Seismic.gmf

*Figure:* B-7

**King County Materials Laboratory**




## *Material Keys*

- Loose Sandy Silt/Silty Sand (fill)
- Dense Silty Gravel
- Dense Poorly Graded Gravel
- Dense Silty Sand/Sandy Silt
- Dense Silty Sand/Sandy Silt (bwt)
- Dense Sandy Silt/Silty Sand
- Riprap
- Medium well graded gravel
- Class B Rock

*Analysis* 1

Multiple Stability Analysis

*Method:* Bishop Simplified

*Surface:* Circular

*Results*

*Critical Factor of Safety:* 1.10

*Edited:* 29 Apr 2019 *Processed* 29 Apr 2019

*Project* Reinig Road: Slope Section C-C
1.5H:1V Rock Slope/2H:1V Upper Soil Slope Low Flow (Seismic(

*File:* S:\PersonalFolders\Doug\Galena Reinig Rd\Reinig Rd Revetment Repair Rock Slope Low Flow Final Seismic.gmf

*Figure:* B-8

**King County Materials Laboratory**